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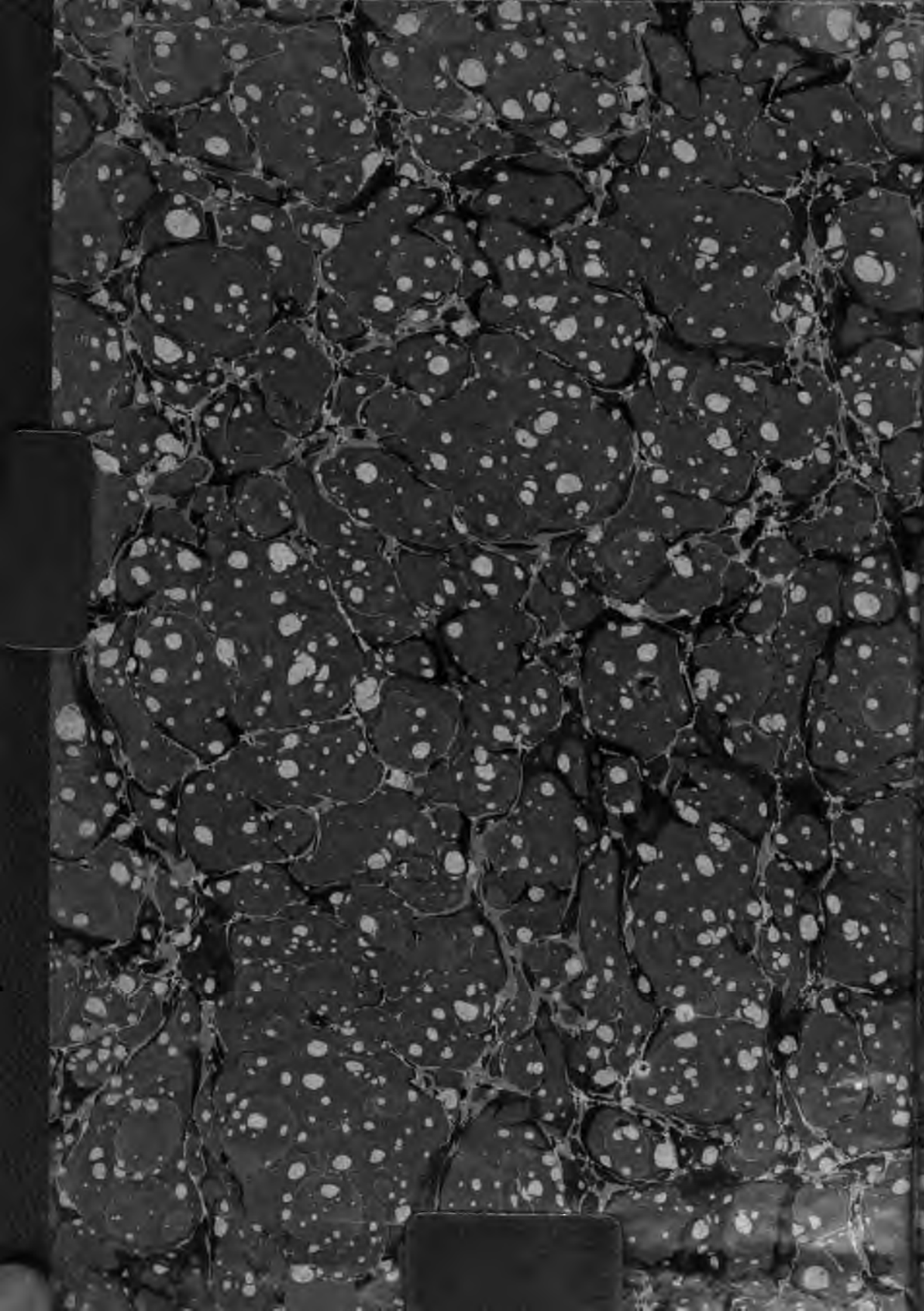

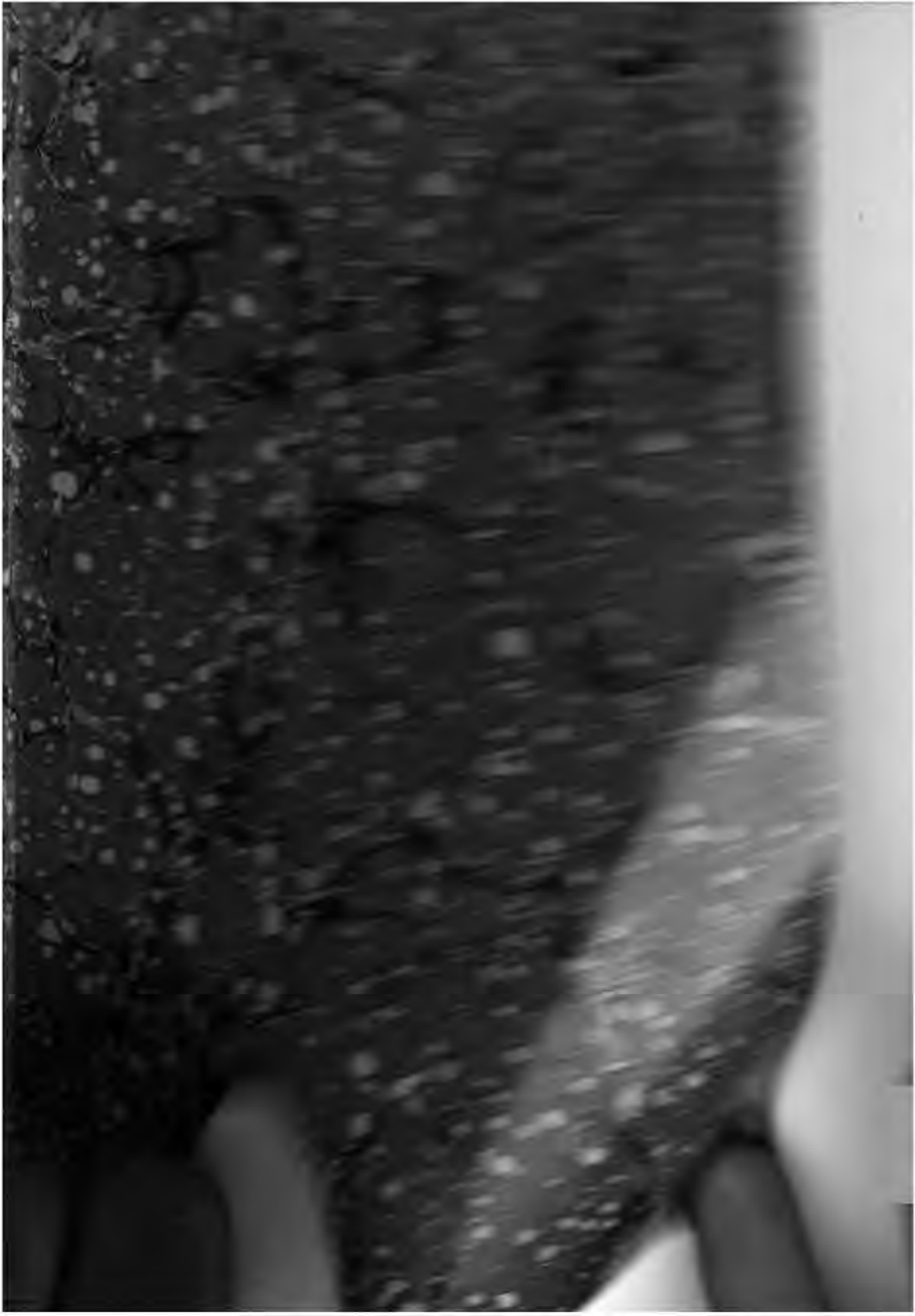

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Terrestrial Magnetism

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VOLUME XVI MARCH, 1911 NUMBER 1

TWO NEW TYPES OF MAGNETOMETERS MADE BY THE DEPARTMENT OF TERRESTRIAL MAGNETISM OF THE CARNEGIE INSTITUTION OF WASHINGTON.

By J. A. Fleming.

The land operations of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington especially in regions more or less difficult of access, have emphasized the need of more portable and more compact instrumental outfits than heretofore in general use, without at the same time sacrifice in requisite accuracy. For the regions here considered, in which the greater part of our work must be done, travel is usually difficult and a bulky and heavy equipment is, accordingly, a serious obstacle to safe transportation and rapid work. The conditions imposed make imperative also the omission of complicated and intricate mechanical devices, the adjustments of which are generally difficult to make and maintain, as well as the avoidance of a great number of loose accessory parts, the loss of any one of which may mean at times either the discontinuance or at least the serious interruption of a campaign. Another essential feature in work of this kind is that the outfit be such to admit advantage being taken of every opportunity for observations; the construction therefore should permit practically *immediate* use and not require what may be the best part of the available time for setting up and assembling various parts.

The controlling conditions in the designs and constructions of the present instruments, as carried out under the direction and in consultation with the Director of the Department, have therefore been: (a) portability; (b) compactness; (c) simplicity; (d) minimum loose accessories; (e) readiness for immediate use; (f) the

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attainment of an absolute observational accuracy equal to that of the best field instruments now in use. The execution of the Director's instructions fell to the writer, who planned the general instrumental designs and details, and under whose supervision the magnetometers were ably and skillfully constructed by the chief mechanician of the Department, Mr. Adolf Widmer.

The new instruments are of two types. The first is a theodolite magnetometer for astronomical work and the determination of declination and horizontal intensity, in general principles along usual lines but differing greatly in details. Mascart had already designed a very portable and ingenious instrument of this kind;[1] an instrument of his type has been used by the Department but the accuracy attanied has not been equal to that of the heavier magnetometers owing perhaps largely to the extreme lightness of the essential parts and especially the very close proximity of the metal portions to the magnet. The second type of instrument of the Department is a universal magnetometer with which the three magnetic elements may be determined as well as the astronomical elements. Wild's[2] universal theodolite for magnetic surveys is too heavy to admit of ready portability, is rather complicated in its construction, has too many accessory parts, and is not readily adapted to quick work. The magnet and suspension systems of the new instruments are of like design and the following details apply for both.

Magnet System and Suspension.

The *magnet system* for either instrument consists of a long and of a short magnet, each a true cylinder, the dimensions being respectively: length 56 and 26 millimeters, outside diameters 7.9 and 6.5 millimeters, and inside diameters 5.6 and 4.5 millimeters. The ratio of the lengths is such as to theoretically eliminate the second distribution coefficient. The magnets are made of a special permanent magnet steel manufactured by the Crucible Steel Company of America. The method of magnetization was substantially that given by Barus[3] The cylinders of steel were ground down to size, next tem-

[1] MASCART, EMILE. Traité de magnetisme terrestre. Paris, 1900 (206–219).

[2] WILD, H. Theodolith für magnetische Landesaufnahmen. Viertel jahrschrift der Naturforschenden Gesellschaft in Zürich. Vol. 41, 1896 (25).

[3] BARUS, CARL. The effects of hardness on the electrical and magnetic constants of steel, with particular reference to the tempering of the magnetic parts of instruments. Jour. Terr. Mag., Vol. 2, 1897 (1 to 10). Also Bulletin of the U. S. Geological Survey, No. 14.

pered "glass hard," and then subjected alternately to the annealing effect of a steam bath at 100° Centigrade for periods of five to six hours, and magnetization in a solenoid for intervals of one to two minutes, each operation being repeated five times. The solenoid consists of 24 layers of 63 turns each of double cotton wound copper magnet wire 1.3 mms. in diameter; length of solenoid is 10.2 cms., outer diameter 8.8 cms., and inner diameter 1.3 cms. A small dynamo supplies current at 20 volts; the resistance of the coil is 3.7 ohms. The magnetic moments of the long magnets so far made average between 280 and 300 C. G. S. units, the intensity of magnetization thus being of the order 210 to 220 C. G. S. units. The loss in the magnetic moments during the past year has averaged but little over one per cent. The induction coefficients average between 0.0094 and 0.0101; the temperature coefficients between 0.00046 and 0.00060.

Each *long magnet* is encased in a heavily gold-plated brass cylindrical sheath which prevents rusting and provides means for mounting the collimating optical system and balancing. The magnet is centered in position by a projecting pin in the bottom of the stirrup which fits snugly in a rectangular groove properly placed in the brass sheath. The reticle consists of two engraved intersecting lines at right angles on a piece of plano-parallel glass mounted at the south end of the sheath so that when using the magnetometer the observer sights towards the magnetic south. The magnet is erect when the numbered and lettered side of the sheath is east; in order to place the magnet quickly the stirrup is provided with a beveled edge a line on which agrees with a corresponding mark on the magnet sheath when the magnet is erect or inverted as the case may be.

Each *short magnet* is similarly encased and provided with the same optical collimating system so that outwardly both long and short magnets are of the same length, diameter, and appearance; the sheaths and balance are also so adjusted as to make both magnets with their attachments of equal weight. The long magnet can therefore be distinguished from the short magnet only by the lettering on the sheaths, *e. g.*, for magnetometer number 12 the lettering is 12*L* and 12*S* at the south ends with the letter *N* at the north ends respectively. Figure 1 shows one of the magnets mounted in its suspension stirrup.

The entire *suspension system* is comparatively free from complex or intricate parts. The devices for clamping the phosphor

bronze ribbon used for the suspension are such that a new ribbon may be very easily and quickly inserted whenever necessary. In replacing the ribbon the entire suspension head including the graduated circle for setting of line of no torsion (see figure 2) may be removed by unscrewing the lower clamp, *A*, at the top of the brass suspension tube below the graduations. It is not really necessary to remove the head as the ribbon may be dropped through it. The hinged clamp plate at the top is loosened by unscrewing its set screw, *B*, better shown in figure 5, and the new ribbon inserted; the new ribbon must be somewhat longer than finally necessary in order to allow clamping at the stirrup end. The clamp plate at the stirrup (see figure 1) may be loosened by its clamp screw, *C*; the new ribbon is then put in place and the clamping plate turned into its proper position and clamped—the screw *C* is so made that it may not be removed and accordingly the clamping plate is always in place. The length of the suspension is then suitably adjusted by drawing it up through the clamp at the top of the tube. It is to be noted that in these arrangements there are no removable parts and therefore no chance of loss of any essential portion.

The *phosphor bronze ribbon* used ordinarily is 0.013 by 0.188 mm. in section; for inertia determinations a grade twice as thick is used. The *torsion* effect for the smaller ribbon amounts to about nine minutes of arc for ninety degrees of twist for the suspension length of these instruments as used at Washington; a lighter ribbon will be used subsequently if it can be supplied by the makers. The effect of torsion can be quite accurately eliminated by the arrangements for the determination of the line or rather plane of no torsion. It will be noted that there is attached permanently to the stirrup (see figures 1 and 5) a graduated circle; this graduation is brought in focus of the telescope (which is previously focused on a distant mark) by interposing an auxiliary lens mounted at the telescope end of the magnetometer house, operated by the milled head, *D*, into the optical axis of the system. The 180-degree division of the two-degree graduation is the division which, when torsion has been removed, being in the axis of the stirrup should be in the line of sight of the magnetometer telescope. The angle of line of detorsion from the axis of the instrument may be quickly determined by noting extreme swings on the graduation of the stirrup when the round brass torsion weight, equal in weight to the long magnet (and also the short one), is suspended; the suspension head may be shifted

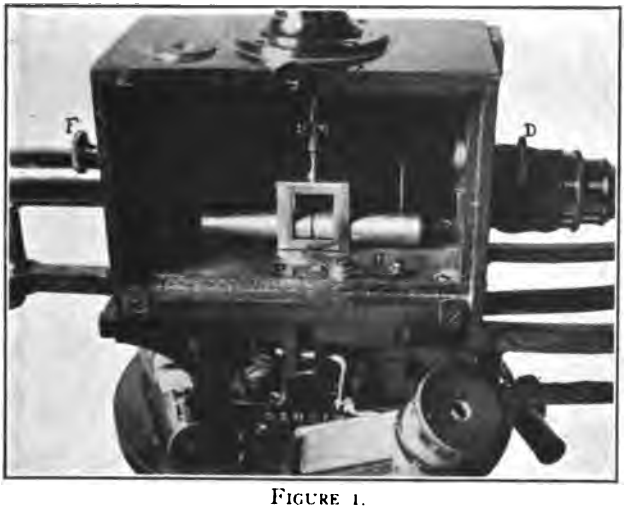


Figure 1.

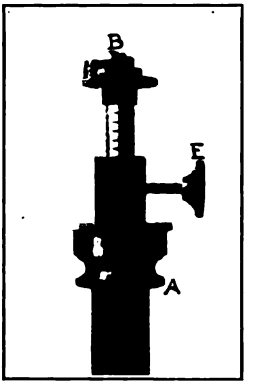


Figure 2.

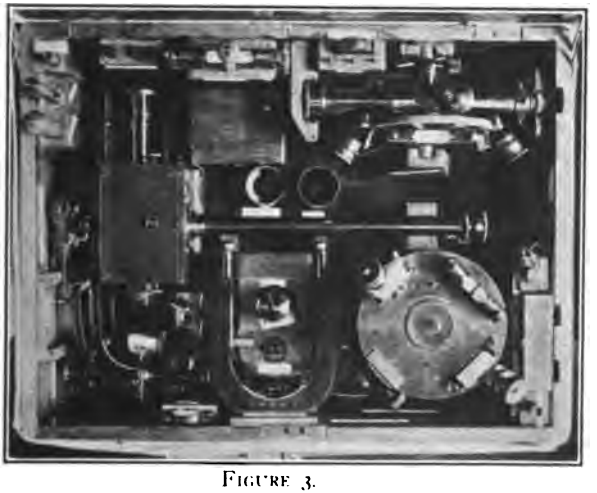
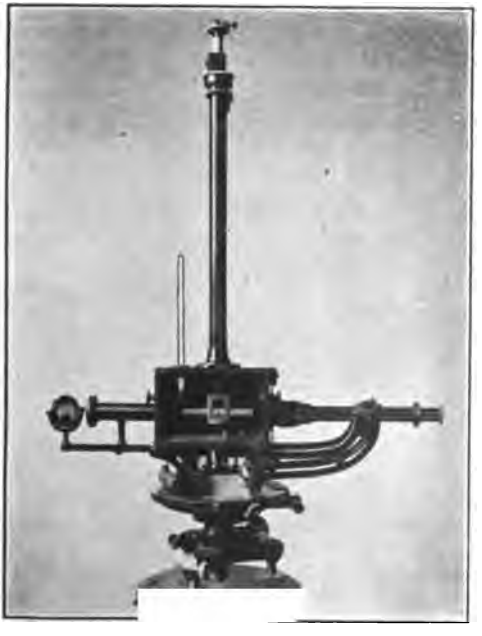


Figure 3.

Figure 4.



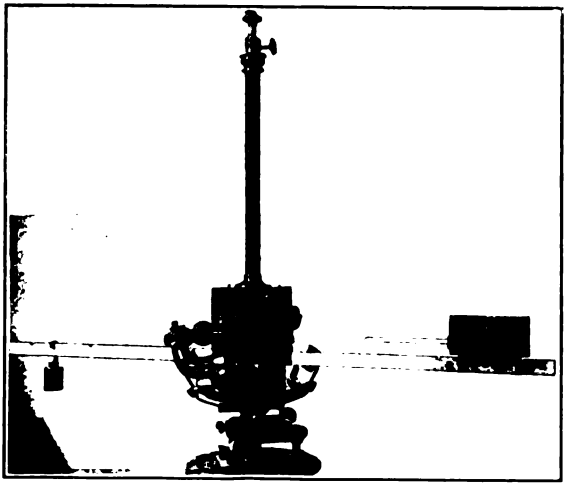


Figure 6.

through this angle after loosening its clamp, *A* (see figure 2); this operation may be repeated until the mean reading on the graduated circle of the stirrup is 180° when the head is clamped in position. For the measurement of torsion effect a graduated circle with fixed index is provided at the suspension head; the graduation is for intervals of ten degrees and such that one degree may be readily estimated. For the determination of detorsion for inertia observations there is provided a brass torsion weight in the shape of a rectangular parallelepiped of suitable size and weight and with a groove for centering in the stirrup.

The *stirrup* is of brass heavily gold-plated to prevent oxidation. It is of rectangular cross section with portions of its sides cut out to reduce its moment of inertia. The width of the stirrup is made equal to the diameter of the magnet sheaths and the length sufficient to insure accurate orientation of the magnets. The height has been made so that an inertia bar, also of the same diameter as the completed magnets, may be mounted in the stirrup on top of the magnet. The inertia bars provided are of the finest grade drawn phosphor bronze rod; they are 56 mms. long and 9.1 mms. in diameter, the moment of inertia being of the order 82 C. G. S. units at 20° Centigrade. The moment of inertia of the long magnet together with stirrup, the attached graduated circle for torsion work, and the suspension is of the order 66 C. G. S. units at the same temperature. To prevent oxidation the inertia bars are gold-plated; for the purpose of centering in the stirrup there is a very light line engraved on the surface and the bar set accordingly by means of the beveled edges of the stirrup. The edges of the stirrup are beveled in order to prevent parallax when inserting inertia bars or magnets. For determining the proper elevation of the stirrup there are two small holes drilled in the deflection box so that when the latter is mounted on the deflection bar the stirrup, and accordingly the suspended magnet, is at the proper elevation when the lower edge of its rectangular opening in the side is centered in the resulting line of sight. These holes are so small as to be in no way detrimental to protection by the box against sudden changes in temperature of the deflecting magnet. The stirrup is readily raised or lowered by means of the rack and pinion arrangement operated by the milled head, *E* (see figure 2), at the top of the suspension tube; to facilitate setting at the proper point there is a graduation provided on the movable centering tube of the suspension head.

There is an *arrester* for the purpose of quieting the motion of the suspended magnet although such an arrangement is not deemed absolutely necessary by experienced observers who make use of the fingers instead. The device (partially shown in figure 1) consists of two arms attached to a bar operated by means of a slow motion mounted on the outside of the magnetometer house (see figure 6, upper right hand corner of telescope end of house). There is only one adjustment provided for the arrester, *viz.*, that of its axis by means of a set screw in collar at the slow motion end; in case the position of the arms relative to the axis must be altered, this may be readily done by slightly bending one or the other arm until the position is such that when the magnet system is released there will be no vertical motion or "bobbing" and the vertical line of the reticle of the magnet will be near the middle division of the telescope scale.

The *scale* by which the position of the collimation lines of the magnets are referred to the horizontal circle setting is composed of sixty divisions engraved on the plano-parallel glass reticle of the magnetometer telescope. The value of one scale interval is two minutes of arc, the line of sight or reference of the magnetometer as regards the horizontal circle being the middle or thirtieth division of the scale. Particular attention has been paid to the engraving of these scales to insure accurate graduations and that the width of the engraved lines are suitably selected to make possible sharp, definite readings and estimations; this is a point frequently overlooked in instruments of otherwise fine construction.

The Theodolite Magnetometer.

The essential units of the instruments are four, *viz.:* (a) the base, center, and horizontal circle; (b) telescope standard frame; (c) telescope and vertical circle, and (d) magnetometer. These are shown in figure 3 which gives a view of the instrument in its packing case. The theodolites are from selected non-magnetic materials carefully tested by the Department and made by the Messrs. C. L. Berger and Sons, of Boston, Massachusetts; the magnetometer parts and appliances, with some slight modifications in the theodolites, were constructed in the instrument shop of the Department.

The *base* is supported by three leveling foot screws. The graduation of the horizontal circle is for thirty minute intervals; there are two verniers the least count of each being one minute of arc, but

one-half minute is quite definitely and easily estimated. The diameter of the graduated circle is 101 mms.

The *telescope standard frame* is made in one U-shaped piece. Two pins are mounted in the base and corresponding holes placed in the bottom of the standard frame to insure invariably the same relation between the two parts when mounted the surfaces in contact being carefully and accurately fitted. The standard frame fits over a threaded projection of the center and is clamped firmly in place by means of a clamping screw plate (partially shown in figure 1) about 5 centimeters in diameter—a loose thin brass washer is interposed to prevent sticking—suitable depressions are made in the upper surface of the screw flange for its operation by the fingers. The same arrangement is used to clamp the magnetometer unit to the base. In setting up for astronomical work the standard frame is placed on the base in its proper position (indicated by corresponding marks on the two parts) and the clamping flange screwed down lightly—no great pressure is needed as the device is very effective.

The *vertical circle and telescope* are then mounted in the standards and the instrument approximately leveled by the base level the sensitiveness of which is about sixty seconds of arc. A stride level is provided for the final leveling; the sensitiveness of this level is from 18 to 20 seconds for the various instruments. The vertical circle is of the same diameter and has the same graduation as the horizontal and is read directly to one minute by two verniers and by estimation to one-half minute. The circle is attached to the telescope, the verniers being fixed in reference to standards. Suitable arrangements are provided for the usual adjustments. The magnifying power of the telescope is 20; the reticle is a simple cross of two fine fibres at right angles. The instrument as used for astronomic work is shown in figure 4.

It will be noted from figure 3 that the *magnetometer* attachment including its telescope and suspension is packed assembled and may be mounted on the base in one operation. Figure 1 shows the device for clamping the stirrup when the instrument is packed away (the magnet is of course first removed). After the magnetometer is set up and properly leveled, the stirrup is quickly unclamped by pushing over the lever, *O*, until stopped by the pin, *P*, and at once raised into position for the insertion of torsion weight and the determination of the plane of detorsion. In order to prevent any wearing action on the top of the graduated circle of the stirrup it should be

noted that the clamp is so arranged that it touches the circle only in its holding position and not while being removed or put in place. The magnetometer house is of wood; this permits observations of oscillations and of deflections in the same housing. The magnetometer telescope, magnifying power 8, is supported by wyes made in the extension of the magnetometer supports carried directly from the base. A *hood,* as in figure 1, attached to the house and fitting over the objective end of the telescope is provided in place of a window to shut out air currents. At the south end of the house there is a plano-parallel glass window which may be turned out of the way, when reading the mark, by means of a milled head, *F,* as in figure 1; this window is of course kept closed while making magnet readings to exclude air currents.

For the *illumination of the magnet* reticle and telescope scale an iris diaphragm and tube (see figure 5) are provided; the opening in the iris diaphragm may be made larger or smaller by motion of a small lever and so regulate the illumination according to the light conditions. A mirror which may be rotated in both the vertical and horizontal planes, with a white reflector on its reverse side, serves to reflect light through the iris diaphragm and tube; it is mounted at the end of the support of the diaphragm tube as shown in figure 5. These illuminating appurtenances are all made removable so that in case it is necessary to use a mark which is not in the horizon they can be taken off and so not interfere with sightings; the telescope end of the hood is provided with a brass collar so that it may be removed from the end of the telescope and the latter have greater vertical motion as may be necessary under the same circumstances. Figure 5 shows the magnetometer with one of the two doors removed and with a magnet suspended in place. The total length of the suspension, *i. e.,* the distance from the bottom of the ribbon clamp at the suspension head to the center of the magnet when in place is from 314 to 364 mms., depending upon the length of ribbon between the upper and lower clamps; ordinarily the total length is about 340 mms. The distance from the top of the clamp of the stirrup to the center of the magnet when suspended is 35.5 mms.

The *deflection bar* for the deflection observations is of rectangular cross section, 5 mms. thick by 15 mms. deep, and is mounted just below the magnet house; the detail of this mounting is shown by figures 1 and 6. The bar is centered and securely held in place by two slightly tapered pins, one at each side of the house. For

centering and protecting the magnet against sudden changes of temperature there is a wood box; the metal supports, wyes, and centers of this housing are complete in themselves, the metal surface bearing on the bar being of sufficient length to insure horizontality of the magnet when mounted in the wyes and centered by a pin fitting snugly in the rectangular groove of the magnet sheath. The lower end of the magnet centering pin of the deflection box is finished to fit snugly in rectangular grooves in the deflection bar at deflection distances 20, 25, and 28 centimeters; the rectangular grooves for centering deflection box have been adopted as they seem somewhat better than the old form of slightly tapering circular holes. For maintaining the vertical plane of the center two broad arms extend down from the metal base the full depth of the deflection bar, against which a heavy spring on the rear side presses them. A suitable counterweight is provided to maintain the level when observing deflections. The instrument as mounted for deflection work, and as seen from the telescope end, is shown in figure 6.

The inside measurements of the *packing case* (see figure 3) are: depth 15 cms. when closed; width 30 cms.; length 42 cms.; the dimensions over all are about 2 cms. greater each way; the *total weight of the instrument and case* is 11 kilograms; that of the older forms of theodolite magnetometers used by the Department twice as much. When account is taken also of the much heavier shipping cases required for the older form of instrument the material reduction in total weight for transportation in the case of the present instrument is made still more apparent. The tripod for the new theodolite magnetometer, as made by Messrs. Berger and Sons, is of the telescoping kind as figure 10, with the exception that the head is somewhat modified to provide means for mounting the Dover dip circle used in connection with this instrument. The deflection bar when in transportation is mounted in its tube case in a hand strap with the tripod; the weight of the tripod and bar is four and one-fourth kilograms against seven and one-half for the tripod and bar of the older form.

The Universal Magnetometer.

This instrument is completely assembled in one unit, comprising astronomical telescope and magnetometer for the determination of magnetic declination and horizontal intensity, and dip circle for determination of inclination and total intensity, and therefore always

ready for immediate use upon mounting on its tripod. The advantage of being able to proceed with the determination of any one of the observations desired at the magnetic station, without first assembling a number of parts, is evident and of peculiar value in taking advantage of every available opportunity for work.

The *base, horizontal circle, and center* are practically identical as regards diameter, graduation, and verniers, with those of the theodolite magnetometer, except a heavy top plate attached to the base to provide means for the securing of the heavier upper works of this instrument. The level attached to the base has a sensitiveness of 30 seconds of arc.

The *astronomical telescope,* magnifying power 18, is mounted eccentrically the distance between the center of the instrument and its vertical plane of collimation being 63 mms. It is provided with a swivelled prismatic eye-piece and suitable shade-glasses for sun work. The single heavy telescope standard is securely mounted on the heavy base casting supporting the magnet house; the bearing for the axis of the telescope is 18 mms. long. This standard also carries the various attachments for dip circle microscopes, vertical circle, reading lenses, clamps, etc. The graduated circle and counterpoise are on the opposite side of the bearing from the telescope and behind a plano-parallel glass window, somewhat greater in diameter than the circle, suitably mounted in the magnet house.

The *vertical circle* is 101 mms. in diameter and graduated for 30 minute intervals, the least count on the two verniers being one minute of arc, but estimations being easily and definitely made for one-half minute. The vertical circle in this instrument is fixed in position, while the verniers move with the telescope. Figure 7 gives a view of the instrument showing various details of the astronomical telescope, vertical circle, magnet house, etc.

The *magnet house* is of old well-seasoned mahogany, carefully finished, polished, and reinforced as necessary to prevent any warping. Figure 8 shows the interior of the house when the instrument is used for magnetic declination and oscillation work. The *magnetometer telescope,* magnifying power 8, is supported in two wyes secured to the base in such a way that its line of sight is central. As will be noted in the figure the wyes are, for economy in packing space, quite near the object end of the telescope which is suitably counterweighted. The counterweight serves the additional purpose of making possible the elimination of the hood arrangement as in the

FIGURE 7.

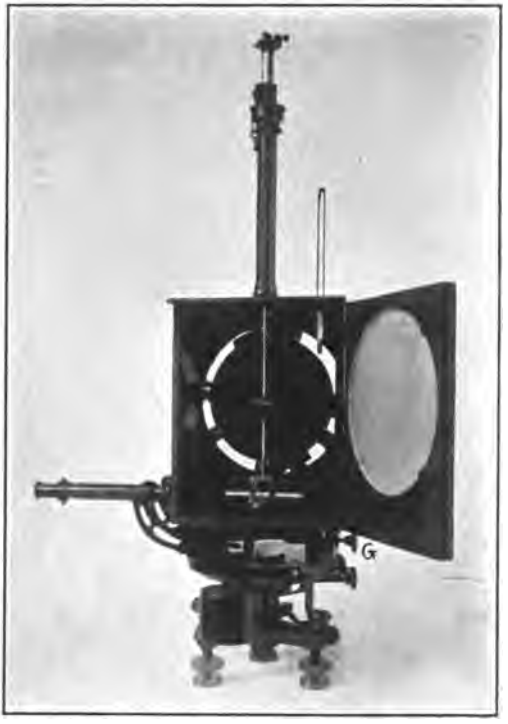


FIGURE 8.

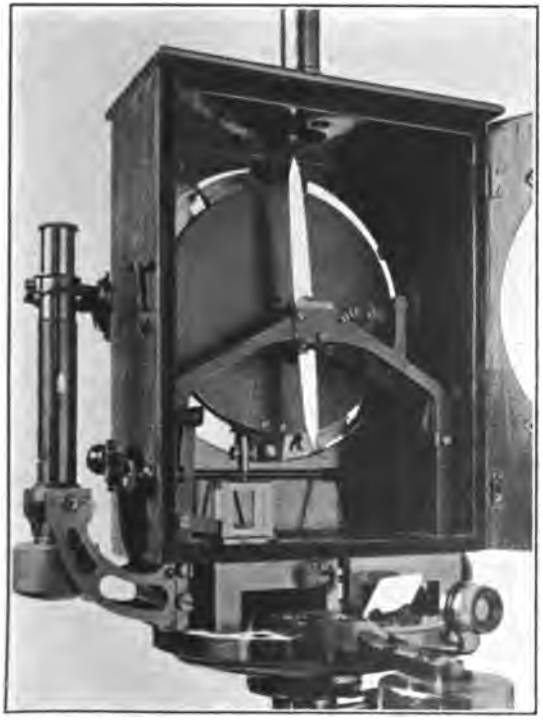


FIGURE 9.

FIGURE 10.

UNIVERSAL MAGNETOMETER.

theodolite magnetometer and which has some objectionable features. The end surface of the counterweight is part of a sphere of large radius; there is a spherical surfaced depression of like size and radius in the outer face of the end of the house; the depression is lined with velvet and so made that when the telescope is horizontal, or nearly so, the two surfaces make a neat fit, thus preventing any currents of air entering the house (see figure 9). The window and illumination device at the south end of the house are somewhat modified over those of the theolodite magnetometer. The plano-parallel glass for keeping out currents of air that might interfere with the suspended magnet, the iris diaphragm, and the mirror and reflector are assembled together, the whole being attached to the box and swinging on a hinge, so that when mark readings are desired the clamping pin may be removed and the system thrown over to prevent interference; when observations are being made it is of course put back into position and clamped. The total length of the suspension, *i. e.,* from the bottom of the clamp of the suspension head to the center of the magnet when mounted is from 326 to 375 mms., depending upon the length of the phosphor-bronze ribbon used. Ordinarily the total length is about 360 mms. The distance between the upper end of the stirrup clamp and the center of the magnet when in position is 32 mms.

The *deflection bar,* box, and counter weight are similar to those above described for the theolodite magnetometer, with the exception of the centering and clamping arrangements for the deflection bar. The casting supporting the magnet house is much heavier than for the theolodite magnetometer and therefore allows of much broader and better bearings, so that the bar for this instrument is firmly held in place by means of but one tapered pin mounted in the center of the instrument; this pin is operated by the milled head *G* (figures 7 and 8). In order to have the center of the house free for the dip work (see figure 9) the stirrup is clamped in one corner and the suspension head sufficiently elevated to make the bronze ribbon nearly taut, and so out of the way. The detail of the clamping arrangement by knee lever and spring is shown in figures 8 and 9 in lower left-hand inside corner of house.

The supports for the agates of the *dip circle,* used for the needle bearings (figure 9), are attached securely to the heavy base independently of the house. They are made of similar shape with the telescope standard in order that there may be as little interference of parts as possible in sighting on the needle points. The needle lifter is operated by means of an eccentric and lever, by a milled head on the south end of the house (see *H,* figure 7). The dip needles were made by Dover, and are of the usual land pattern, except as regards length, being somewhat longer in order that the ends may project beyond the vertical circle. The sighting microscopes are a little unusual in that the object lenses are mounted inside of the house fixed permanently to the counterpoise plate so as

to move with the verniers, while the remainder of the optical arrangements are mounted outside; this has been found quite satisfactory. It should be noted that no matter what position the needle may take it is always possible to read the upper end; it is a comparatively easy matter to supply the data for those parts of the circle where the lower end is obscured by interference of supports by observations made on either side.

Total intensity arrangements according to Lloyd's method are also provided, the deflecting needle being mounted on suitable supports attached to the telescope, which is at right angles to the line of sight of the microscopes. The instrument is equipped with two pairs of dip needles and two pairs of intensity needles, together with all necessary appurtenances, as reversing block, bar magnets, etc.

Figure 10 shows the magnetometer mounted on its *tripod.* The latter has legs of a telescoping pattern; this style, unless carried in the hand, is rather inconvenient for packing, as the numerous screws and nuts are quite likely to be bent. It is therefore expected in the next universal magnetometer to provide a tripod somewhat similar to the pattern usually supplied with the Dover dip circles, which is not much heavier and of simpler construction than the one shown.

The inside measurements of the *packing case* are: depth with door closed, 21 cms.; width, 25 cms.; height, 49 cms.; the dimensions over all are about 2 cms. greater each way. The weight of the instrument with all of its appurtenances, but exclusive of the case is 7¼ kilograms. That of the case about 6 kilograms, the total weight being about 13 kilograms. The weight of the instrumental outfit consisting of dip circle and magnetometer usually supplied is more than twice as much; when account is taken of the transportation cases, three to four times as great. The weight of the tripod as in figure 10, with deflection bar, is 4¼ kilograms; the new form referred to above will be of about the same weight.

The *corrections* of the new instruments on the provisional International Magnetic Standards of the Department have been carefully determined by the method of simultaneous intercomparisons with standard field instruments. The type of standard instrument of the Department has beeen subjected to a peculiarly severe test as regards accuracy in the numerous intercomparison observations that have been made at various observatories; the results have been such as to indicate *absolute* accuracy in magnetic determinations of the order of 0.5 minute in declination, 0.02 per cent in horizontal intensity (.0002H), and about one-half minute in inclination. The results of the comparisons of the new instruments have clearly shown that their accuracy is of the same order.

Department of Terrestrial Magnetism,
Carnegie Institution of Washington.

THE PECULIAR MAGNETIC DISTURBANCES OF DECEMBER 28-31, 1908.[1]

By R. L. Faris.

In the March, 1909, number of this Journal,[2] Mr. D. L. Hazard called attention to the peculiar features of some magnetic disturbances which occurred on December 29 and 30, 1908, and described their characteristics as shown on the records of the Cheltenham Observatory, comparison also being made of their features as recorded at the other observatories of the Coast and Geodetic Survey. These disturbances being of such special interest, occurring as they did, as definite perturbations of about half an hour's duration during a period when the magnetic conditions were everywhere exceptionally quiet, it was suggested by Dr. L. A. Bauer that it would be worth while to examine the records of other observatories in order to ascertain if similar disturbances were recorded in other parts of the world. Accordingly, with this point in view, many of the observatories were asked to supply the desired data as outlined in the following extract from the letter of the Superintendent of the Coast and Geodetic Survey, Mr. O. H. Tittmann, under date of May 21, 1910, addressed to the directors of various magnetic institutions:

Dear Sir: Will you please forward to me at your earliest convenience, for the use of the Division of Terrestrial Magnetism, copies of your photomagnetic curves (magnetograms) covering the period from the beginning of December 29th to the end of December 31st, Greenwich civil date, 1908, with all the necessary data for reading the ordinates and converting them into absolute measure. In order to serve as a check on our own readings, please send also your hourly readings for these days, and the mean hourly values for the entire month.

The above mentioned magnetograms are of special interest, and I trust that you will not find it troublesome to comply with the request.

The foregoing letter was addressed to forty-eight observatories and institutions engaged in magnetic observational work; of these up to the present time replies have been received from thirty-one, thirteen of which were unable to supply the data requested, and from seventeen no word of response has been received to date (Dec. 5th).

Opportunity is here again taken to express the thanks of the Division of Terrestrial Magnetism of the Coast and Geodetic Survey for the prompt and complete response to the request for the observa-

[1] Published by permission of the Superintendent of the United States Coast and Geodetic Survey.

[2] *Terr. Mag.*, v. 15, pp. 37-38.

TABLE I.—*Geographic Positions of Observatories and Approximate Values of the Magnetic Elements for December, 1908.*

OBSERVATORY	GEOGRAPHIC POSITION			MAGNETIC ELEMENTS (Dec. 1908)			DIRECTOR OR OBSERVER-IN-CHARGE	TYPE OF MAGNETOGRAPH	REMARKS
	Latitude	Longitude	Longitude	Decl'n D	Hor. Int. H	Vert. Int. Z			
	° ′	° ′	h m	° ′	γ	γ			
Porto Rico.....	18 09 N	65 27 W	— 4 21.8	2 07 W	29017	+34185	G. Hartnell	Eschenhagen	
Cheltenham	38 44 N	76 50 W	— 5 07.3	5 34 W	19908	+56323	J. E. Burbank	Eschenhagen	
Agincourt[1]	43 47 N	79 16 W	— 5 17.1	5 57 W	16337	.....	W. Mengies	Adie	
Baldwin	38 47 N	95 10 W	— 6 20.7	8 33 E	21677	+55959	W. B. Keeling	Eschenhagen	
Sitka	57 03 N	135 20 W	— 9 01.3	30 12 E	15568	+56573	H. M. W. Edmonds	Eschenhagen	
Honolulu	21 19 N	158 04 W	—10 32.3	9 26 E	29167	+24390	W. F. Wallis	Eschenhagen	
Alibág	18 38 N	72 52 E	+ 4 51.5	1 02 E	36860	+15956	N. A. F. Moos	Watson	Bombay.
Batavia	6 11 S	106 50 E	+ 7 07.3	0 50 E	36702	—22134	W. van Bemmelen	Wild	
Lu-kia-pang	31 21 N	121 01 E	+ 8 04.1	2 38 W	33110	+33780	J. de Moidrey	Adie	Zi-ka-wei.
Tokio	35 41 N	139 45 E	+ 9 19.0	4 54 W	30000	+34454	T. Yoshida	Mascart	
Mauritius	20 06 S	57 33 E	+ 3 50.2	9 15 W	23415	—31932	T. F. Claxton	Adie	
Helwan	29 52 N	31 21 E	+ 2 05.4	2 53 W	30030	+25790	H. E. Hurst	Watson	
Pola	44 52 N	13 51 E	+ 0 55.4	8 40 W[2]	22202[2]	+38616[2]	W. v. Kesslitz	Eschenhagen	
Seddin	52 17 N	13 00 E	+ 0 52.0	9 16 W	18885	+42962	A. Schmidt	Schmidt-Toepfer	Potsdam.
Copenhagen	55 51 N	12 27 E	+ 0 49.8	9 40 W	17394	+44763	V. Hjart	Mascart	Rude Skov.
Munich[1]	48 09 N	11 37 E	+ 0 46.5	9 44 W	20639	.....	J. B. Messerschmitt	Edelmann	
Wilhelmshaven[1] ..	53 32 N	8 09 E	+ 0 32.6	11 52 W	18150	.....	H. Cappelle	Adie	
De Bilt	52 06 N	5 11 E	+ 0 20.7	13 10 W	18556	+43255	G. van Dijk	Toepfer	
Uccle	50 48 N	4 22 E	+ 0 17.5	13 33 W	19048	+42813	G. Lecointe	Mascart	
Val-Joyeux	48 49 N	2 01 E	+ 0 08.1	14 37 W	19731	+41799	Th. Moreaux	Mascart	
Kew[1]	51 28 N	0 19 W	— 0 01.3	16 14 W	18516	.....	C. Chree	Adie	
Falmouth	50 09 N	5 05 W	— 0 20.3	17 52 W	18800	+43280	E. Kitto	Adie	

[1] No record of *Z*. [2] Mean for the day.

tional data. Some of the existing observatories were inadvertently omitted in the request. All the data received concerning these very interesting magnetic disturbances have been included in the following tabulations.

Table I is self-explanatory except in the case of the columns of "Magnetic Elements," which are the mean values as given for the month of December, 1908, except for Pola, where the mean values of December 30th are given. The column of Director or Observer-in-Charge, is as nearly correct as the information at hand would permit. The intensities are expressed in gammas ($1\gamma = 0.00001$ C. G. S.).

Fig. 1, which is reproduced from tracings of the photomagnetic curves, shows the three principal types of the record of the disturbance of December 29, 1908, and are here given especially for convenient reference in describing the character of the record of the disturbance at the different observatories herein considered. In Table II the Cheltenham curves are referred to as type (A), Baldwin curves as type (B), and Honolulu as type (C).

TABLE II. *Relative character of the disturbance deflection curves, December 29 31, 1908.*

OBSERVATORY	TYPE OF DEFLECTION			OBSERVATORY	TYPE OF DEFLECTION		
	D	H	Z		D	H	Z
	December 29, 1908				December 30, 1908		
Porto Rico	(B) H	a	(B) H	Alibág	(C)	(C)	(C)
Cheltenham	(A)	(A)	(A)	Mauritius	(B) Z	(A) D	(B)
Agincourt	(B) H	(B)	b	Helwan	(B) H	(C)	(C)
Baldwin	(B)	(B)	(B)	Pola	(B) H	(B)	(C)
Sitka	(C)	(C)	(C)	Seddin	(B) H	(B)	(C)
Honolulu	(C)	(C)	(C)	Copenhagen	(B) H	(B)	(C)
				Munich	(C)	(B)	b
				Wilhelmshaven	(B) H	(B)	b
	December 30, 1908			De Bilt	(C)	(A)	(C)
				Uccle	(C)	(B)	(C)
Alibág	(C)	(C)	(C)	Val-Joyeux	(C)	(B)	(C)
Batavia	(C)	(C)	(C)	Kew	(C)	(B(	d
Lu-kia-pang	(C)	(A)	(C)	Falmouth	(C)	(B)	(C)
Tokio	(B) H	(B)	(B)				
	December 31, 1908						
Alibág	(A)	(C)	(C)				
Batavia	c	(A)	(C)				
Lu-kia-pang	(A) H	(A)	(C)				
	(B) H	(B)	c				

a Not working freely.
b No Z-instrument in operation.
c Motion indefinite or not discernible.
d Record too disturbed by electric currents.

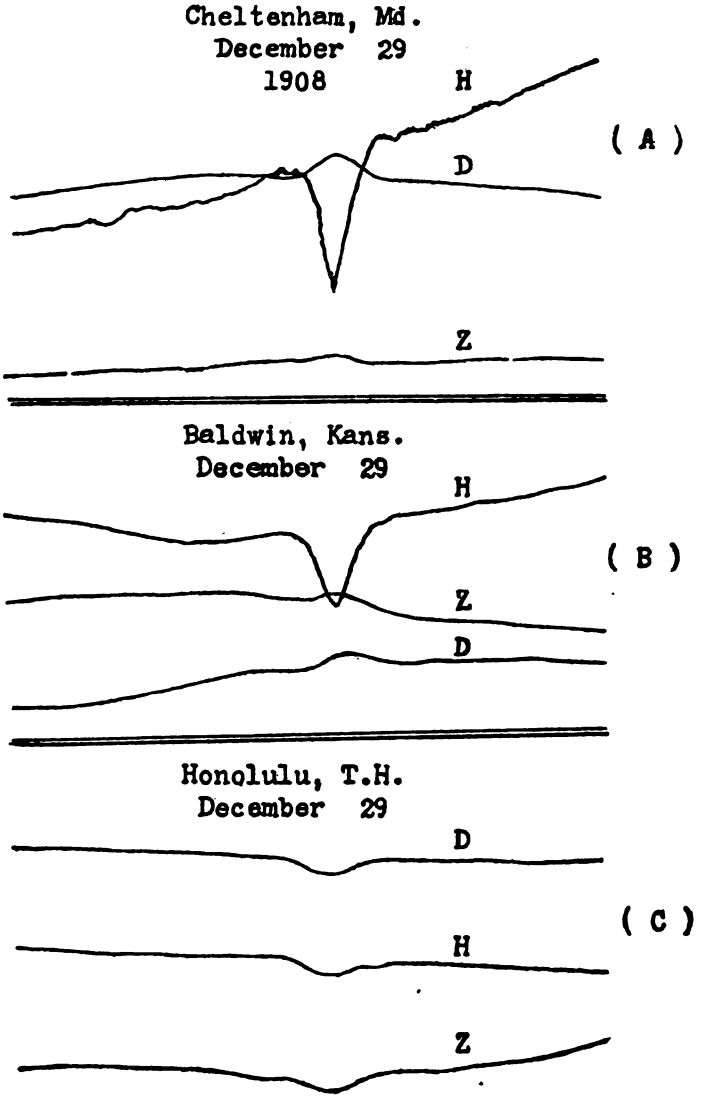


FIG. 1. *Showing Character of Disturbance at Cheltenham, Dec. 29, 1908.*

Table II describes in a general way the appearance of the disturbance in comparison with the three principal characteristics in Fig. 1. (*A*), (*B*), and (*C*) refer to the Cheltenham, Baldwin, and Honolulu types, respectively, and where these symbols appear in any of the columns of the table it means that the disturbance is similar to the curve so marked in Fig. 1; for example, a (*B*) in column headed *D* means that the disturbance curve is similar to the *D-curve* at Baldwin, and a (*B*) in the H-column means that the disturbance curve is like the H-curve at Baldwin, and so on. The letter D, H, or Z after the symbol (*A*), (*B*), or (*C*) means that the disturbance curve resembled the D, H, or Z curve of the type represented by the symbol; *e. g.*, (B) H in the D column for Porto Rico means that the declination curve at Porto Rico resembled the H curve at Baldwin. It is to be noted that the deflections described were not in all instances exactly like the types assigned to them in the table, but the assignments given are those most nearly representing the actual forms of the curves.

Table III contains the Greenwich mean civil times of beginning, maximum, and ending of the disturbances for all three elements as scaled from the records of the various observatories named in the first column of the table, the hours being counted continuously from midnight, 0^h, to midnight 24^h. The observatories are grouped in accordance with date of occurrence of the disturbance, and groups I and III with increasing west longitude, groups II and IV being with increasing east longitude. The times were scaled off with a millimeter scale, tenths of millimeters being estimated. In those records where the time data were given in local mean time, the scalings were corrected for parallax (overlap) and error of the driving clock of the recording apparatus on local mean time, and then this corrected local mean time was converted into Greenwich mean time. In a number of the copies of the records received, these corrections had already been made in making the tracings from the originals, that is, the curves were adjusted to Greenwich mean time, or else to Standard time.

The beginning of the disturbance deflection was considered to be the point where the curve began to deviate from its quiet, undisturbed course, and the end at the point where the curve assumed its normal course again; the time of maximum of course being scaled from the point of maximum deflection.

The times are given to tenths of minutes, but it must not be

TABLE III.—*Greenwich mean civil times of beginning, of maximum, and of end of disturbance, Groups I, II, III, and IV.*

Group I. December 29, 1908.

Observatory	Longitude in degrees	Time of Beginning			Time of Maximum			Time of End		
		D	H	Z	D	H	Z	D	H	Z
	° ′	h m	h m	h m	h m	h m	h m	h m	h m	h m
Porto Rico....	65 27 W	17 36.9	(b)	17 36.8	17 52.5	(b)	17 50.6	18 03.9	(b)	18 07.1
Cheltenham ...	76 50 W	36.3	17 34.3	36.9	51.0	17 50.2	54.6	09.0	18 06.1	05.1
Agincourt	79 16 W	35.6	35.9	(a)	51.0	50.4	(a)	05.8	04.9	(a)
Baldwin	95 10 W	37.9	36.9	37.3	55.6	52.2	52.0	12.7	07.2	04.4
Sitka	135 20 W	37.2	33.1	37.8	52.5	42.1	44.5	01.9	17 59.8	(b)
Honolulu	158 04 W	36.5	37.7	39.7	51.2	51.5	55.6	(b)	18 15.2	18.7
Means	.....	17 36.7	17 35.6	17 37.7	17 52.3	17 49.3	17 53.3	18 05.6	18 06.6	18 08.8

Group II. December 30, 1908.

Mauritius	57 33 E	2 27.2	2 14.5	2 21.8	.....	.....	.....	2 52	2 40	.....
Alibág	72 52 E	17.3	12.5	1 48.9	2 34.9	2 31.3	2 24.3	50.9	52.5	2 42.1
Batavia	106 50 E	14.9	08.5	2 18.4	30.0	33.3	34.2	50.1	56.5	55.3
Lu-kia-pang ..	121 26 E	(b)	12.8	20.5	(b)	27.1	39.5	(b)	51.5	74.7
Tokio	139 45 E	18.2	14.2	22.2	26.1	26.1	30.0	41.9	45.8	60.4
Honolulu	158 04 W	17.3	18.3	13.3	.....	.....	.....	37	.....	33
Means	.....	2 19.0	2 13.5	2 14.2	2 30.3	2 29.4	2 32.7	2 46.4	2 49.3	2 53.1

Group III. December 30, 1908.

Alibág	72 52 E	10 33.7	10 36.5	10 39.7	10 58.5	10 48.5	10 56.5	11 17.3	11 24.5	11 20.5
Mauritius	57 33 E	31.9	22.0	22.5	47.6	47.2	(b)	20.2	13.2	(b)
Helwan	31 21 E	32.2	(b)	23.8	46.6	39.8	40.2	17.0	18.6	10 50.6
Pola	13 51 E	31.4	34.8	34.8	46.7	48.9	48.9	05.0	09.9	11 02.4
Seddin	13 00 E	36.7	37.0	37.4	52.0	52.6	54.2	25.0	13.9	11.3
Copenhagen ..	12 27 E	32.0	36.2	35.0	47.0	49.1	46.6	02.0	13.7	02.1
Munich	11 37 E	35.4	37.0	(a)	53.7	51.4	(a)	06.9	15.9	(a)
Wilhelmshaven	8 09 E	35.4	38.2	(a)	51.1	51.1	(a)	13.0	09.1	(a)
De Bilt	5 11 E	34.8	35.6	31.2	52.2	49.2	54.0	20.4	14.4	09.0
Uccle	4 22 E	35.6	39.1	32.9	54.1	53.4	61.6	21.1	22.1	24.0
Val-Joyeux ...	2 01 E	37.8	37.2	(?) 20.4	57.0	55.2	49.8	29.4	25.2	06.0
Kew	0 19 W	35.0	35.0	(c)	50.8	59.0	(c)	13.2	19.0	(c)
Falmouth	5 05 W	32.0	44.8	31.0	53.2	52.8	53.0	(b)	17.6	13.3
Porto Rico....	65 27 W	36.8	35.8	36.8	.....	.....	.....	05	10	07
Means	.....	10 34.3	10 36.1	10 31.4	10 51.6	10 50.6	10 51.6	11 15.0	11 16.2	11 08.6

Group IV. December 31, 1908.

Mauritius	57 33 E	none	3 20.8	none	.....	.....	.....	.....	(b)	.....
Alibág	72 52 E	3 52.5	23.3	3 33.7	4 06.5	3 34.5	4 00.5	4 26.9	4 00.5	4 13.7
Batavia	106 50 E	(b)	29.9	71.5	(b)	4 06.6	23.4	(b)	33.7	(b)
Lu-kia-pang ..	121 26 E	55.0	55.0	63.9	06.6	06.6	17.6	43.3	25.2	(b)
Tokio	139 45 E	56.8	59.2	(b)	06.3	07.1	(b)	4 26.7	36.1	(b)
Honolulu	158 04 W	20.3	25.7	27.2	.....	.....	.....	3 47	40	(b)
Means	.....	3 46.2	3 35.6	3 49.1	4 06.5	3 58.7	4 13.8	4 32.3	4 23.9	4 13.7

(a) No Z-instrument in operation. (b) Motion indefinite, or not discernible.
(c) Record too disturbed by electric currents.

TABLE IV.—*Duration of the disturbances, and maximum deflections.*

Group I. December 29, 1908.

OBSERVATORY	Duration of Disturbance			Maximum Deflection			Average Duration..	Character of Day.....
	D	H	Z	D	H	Z		
	m	m	m	′	γ	γ	m	
Porto Rico.....	27.0	(b)	30.9	−2.5	−(b)	+10.0	29.0	1
Cheltenham	32.7	31.7	28.2	−3.2	−36.5	+ 2.8	30.9	0
Agincourt	30.2	29.0	(a)	−3.3	−15.8	(a)	29.6	(d)
Baldwin	34.8	30.3	27.1	−1.5	−39.0	− 9.1	30.7	1
Sitka	24.7	33.5	(b)	+2.0	− 4.0	− 2.0	29.1	1
Honolulu	(b)	37.5	39.0	+2.0	− 6.0	+ 5.4	38.2	0
Means	29.9	32.4	31.3					

Group II. December 30, 1908.

Mauritius	25	25	(b)	+1.3	+ 5.0	− 2.0	25	(d)
Alibág	33.6	40.0	53.2	+1.0	− 6.4	+13.1	42.3	1
Batavia	35.2	48.0	36.9	−2.2	+12.3	+ 5.4	40.0	1
Lu-kia-pang	(b)	38.7	54.2	(b)	−24.1	− 7.6	46.4	1
Tokio	23.7	31.6	38.3	+0.9	−25.2	−10.4	31.2	(d)
Honolulu	20	(b)	20	−0.3	+ 2.0	− 1.0	20	0
Means	27.5	36.7	40.5					

Group III. December 30, 1908.

Alibág	43.6	48.0	40.8	+0.5	+ 5.1	+ 6.3	46.2	0
Mauritius	48.2	51.2	(b)	+0.6	+14.0	+ 5.0	51.2	(d)
Helwan	45.8	(b)	26.8	−3.6	+ 9.8	− 6.0	36.2	0
Pola	33.6	35.1	27.6	−2.6	−17.3	− 6.3	32.1	0
Seddin	48.3	36.9	33.9	−2.6	−20.1	+ 5.5	32.1	0
Copenhagen	30.0	37.5	27.1	−1.9	−13.0 (?)	−10.0 (?)	31.5	(d)
Munich	31.5	38.9	(a)	−2.5	−18.7	(a)	35.2	0
Wilhelmshaven ...	37.6	30.9	(a)	−3.3	−19.8	(a)	34.2	0
De Bilt	45.6	38.8	37.8	−2.1	−27.3	+ 7.2	40.7	1
Uccle	45.5	43.0	51.1	−1.8	−17.5	+ 8.8	44.9	(d)
Val-Joyeux	51.6	48.0	45.6	−2.9	−26.2	− 5.0	46.3	0
Kew	38.2	44.0	(c)	−3.5	− 7.5	(c)	41.1	0
Falmouth	(b)	32.8	42.3	−1.4	−22.5	− 4.8	37.6	0
Porto Rico	28	34	30	+0.3	(b)	− 3.3	30.7	1
Means	40.5	39.9	35.8					

Group IV. December 31, 1908.

Mauritius	....	(b)	....	.....	+10.0	.....	....	(d)
Alibág	34.4	37.2	40.0	+1.0	+ 5.1	+ 8.4	37.2	0
Batavia	(b)	63.8	(b)	−(b)	+23.6	−10.0	63.8	1
Lu-kia-pang	48.3	29.6	(b)	−2.3	−13.6	− 5.2	39.0	1
Tokio	29.9	36.9	(b)	+1.3	−13.8	−(b)	33.4	(d)
Honolulu	27	14	(b)	+0.3	+ 1.3	− 2.0	20.5	0
Means	34.9	37.8	40.0					

a) No Z-instrument in operation. (b) Motion indefinite or not discernible. (c) Record too disturbed by electric currents. (d) Not given in report of International Commission on Terrestrial Magnetism for December, 1908.

TABLE V.—*Rectangular components for maximum deflections, Groups I, II, III, IV.*

Observatory	Maximum Deflection ΔX	ΔY	ΔZ
Group I. December 29, 1908.			
	γ	γ	γ
Porto Rico	— 0.8	—21.1	+10.0
Cheltenham	—38.1	—14.9	+ 2.8
Agincourt	—17.3	—14.0	(a)
Baldwin	—37.2	—15.2	— 9.1
Sitka	— 8.1	+ 5.8	— 2.0
Honolulu	— 8.7	+15.7	+ 5.4
Group II. December 30, 1908.			
Mauritius	+ 6.3	+ 7.9	— 2.0
Alibág	— 6.6	+10.6	+13.1
Batavia .....S	+12.6	—23.3	+ 5.4
Lu-kia-pang	—24.1	+ 1.1	— 7.6
Tokio	—24.4	+10.0	—10.4
Honolulu	+ 2.4	— 2.2	— 1.0
Group IV. December 31, 1908.			
Mauritius	+ 9.9	— 1.6	.....
Alibág	+ 4.9	+10.8	+ 8.4
Batavia	+23.6	+ 0.3	—10.0
Lu-kia-pang	—14.6	—21.5	— 5.2
Tokio	—12.7	+10.1	—(b)
Honolulu	+ 0.9	+ 2.7	— 2.0

Observatory	Maximum Deflection ΔX	ΔY	ΔZ
Group III. December 30, 1908.			
	γ	γ	γ
Alibág	+ 5.0	+ 5.5	+ 6.3
Mauritius ...S	+14.5	— 1.7	+ 5.0
Helwan	—11.4	—30.9	— 6.0
Pola	—19.6	—14.0	— 6.3
Seddin	—22.1	—10.9	+ 5.5
Copenhagen ...	—14.4	— 7.3 (?)	—10.0 (?)
Munich	—20.9	—11.6	(a)
Wilhelmshaven	—22.9	—12.9	(a)
De Bilt	—29.2	— 4.8	+ 7.2
Uccle	—19.4	— 5.6	+ 8.8
Val-Joyeux ...	—29.6	— 9.5	— 5.0
Kew	—12.5	—16.0	(c)
Falmouth	—23.7	— 0.4	— 4.8
Porto Rico....	+ 0.1	+ 2.5	— 3.3

(a) No Z-instrument in operation. (b) Motion indefinite or not discernible.
(c) Record too disturbed by electric currents.

considered that the actual times of the disturbance at the various places are known to that degree of accuracy, especially, as in many instances it was impossible to know within several minutes of time just where the beginning (or ending) of the disturbance should be taken on the curve, the beginning and ending of the disturbances being so very gradual. In some cases the times are not given, and are marked "indefinite or not discernible," and in these instances the disturbance was either not definite enough to differentiate from other existing slight deviations on the curve, or no deflection at all was discernible on that part of the curve where it should have occurred.

Table IV gives the duration of the disturbance deflection for the three elements D, H, and Z, obtained from the times as given in Table III. Columns five to eight contain the amounts of the deflections at the maximum portion. These were obtained by drawing, across the disturbed interval of the curve, a line in the position the normal curve would have had if the disturbance had not occurred, this being in general accomplished by connecting the record of the beginning and end of the disturbance by a straight line. The distance from the maximum portion of the disturbed part of the curve to this line was then scaled off, the direction of measurement, of course, being normal to the base line of the element measured. These measurements were then converted into the respective elements (D, H, and Z), and as these ordinates were in all cases comparatively quite small, no corrections were considered necessary.

In the last column of this table the "magnetic character" of the day is given, as taken from the published list of "Magnetic Character of Days" by the International Commission on Terrestrial Magnetism. In eight instances the magnetic character is given as 1. After examining the curves for those days I was convinced that but for the presence of the peculiar disturbance under investigation, those days would have all been given the "magnetic character" zero (of the international scale), as the curves otherwise indicated an exceptionally magnetically calm period existing at that time. In the table a plus (+) sign for H and Z means increasing horizontal and vertical intensity respectively, a minus (—) sign of course meaning the reverse of the foregoing, and a plus (+) sign in D indicates motion to the eastward, a minus (—) sign, to westward.

In the above tables, No. V contains the ΔX, ΔY, and ΔZ of the maximum deflection at all of the observatories mentioned in Table

TABLE VI.—*Deflections at different intervals during the disturbance, as recorded at the Coast and Geodetic Survey Observatories, Dec. 29, 1908.*

Observatory	Quantity	Deflections at Greenwich Mean Civil Time				
		$17^h\ 40^m$	$17^h\ 46^m$	Maximum	$17^h\ 52^m$	$17^h\ 58^m$
Porto Rico	Δ D	— 0.3′	— 1.3′	— 2.5′	— 2.3′	— 1.1′
	Δ H	(a)	(a)	(a)	(a)	(a)
	Δ Z	+ 2.2γ	+ 8.2γ	+10.0γ	+ 9.3γ	+ 4.4γ
	Δ X	— 0.1	— 0.6	— 0.8	— 0.7	— 0.3
	Δ Y	— 2.5	—11.0	—21.1	—19.4	— 9.3
Cheltenham	Δ D	— 0.7′	— 2.2′	— 3.2′	— 3.2′	— 2.4′
	Δ H	— 7.2γ	—27.0γ	—36.5γ	—25.1γ	— 6.3γ
	Δ Z	+ 1.1	+ 2.2	— 2.8	+ 2.6	+ 1.1
	Δ X	—11.1	—28.1	+38.1	—26.8	— 7.6
	Δ Y	— 3.3	—10.1	—14.9	— 16.0	—13.2
Baldwin	Δ D	— 0.3′	— 0.9′	— 1.5′	— 1.5′	— 0.3′
	Δ H	— 5.0γ	—20.9γ	—39.0γ	—39.0γ	—12.7γ
	Δ Z	— 1.0	— 4.3	— 9.1	— 9.1	— 3.8
	Δ X	— 4.6	—19.9	—37.2	—37.2	—12.3
	Δ Y	— 2.6	— 8.7	—15.2	—15.2	— 3.8
Sitka	Δ D	+ 0.6′	+ 1.4′	+ 2.0′	+ 1.2′	+ 1.0′
	Δ H	— 3.6γ	— 2.4γ	— 4.0γ	— 3.6γ	— 0.4γ
	Δ Z	— 0.8	— 1.3	— 2.0	— 0.7	— 0.5
	Δ X	— 4.5	— 5.3	— 8.1	— 5.8	— 2.6
	Δ Y	+ 0.5	+ 4.3	+ 5.8	+ 2.4	+ 3.7
Honolulu	Δ D	+ 0.9′	+ 1.7′	+ 2.0′	+ 2.0′	+ 1.3′
	Δ H	— 1.6γ	— 4.4γ	— 6.0γ	— 6.0γ	— 3.6γ
	Δ Z	+ 0.2	+ 1.0	+ 5.4	+ 5.2	+ 3.8
	Δ X	— 2.9	— 6.7	— 8.7	— 8.7	— 5.4
	Δ Y	+ 7.2	+13.5	+15.7	+15.7	+10.3

(a) Motion indefinite or not discernible.

TABLE VII.—*Times of occurrences of other disturbances similar to those in Table III.*

Group A.

OBSERVATORY	DATE, 1908	TIME OF BEGINNING			MAXIMUM DEFLECTION			DURATION (APPROX.)		
		D	H	Z	D	H	Z	D	H	Z
		h m	h m	h m	′	γ	γ	m	m	m
Honolulu	Dec. 28,	17 15.0	17 17.3	17 16.0	+0.5	— 2.0	+1.3	26	32	30
Sitka	"	none	none	none						
Baldwin.....	"	none	17 17.2	17 17.6	....	— 7.0	—3.0	...	30	30
Agincourt	"	17 14.0	17 15.6	no record	—0.6	— 2.7	....	25	36	...
Cheltenham	"	17 17.1	17 15.6	17 18.7	—0.8	— 6.8	+1.7	24	24	18
Porto Rico	"	17 17.0	indef.	17 16.0	(—)	.....	(+)	Def'n	Obs'	ns.
Falmouth	"	none	none	none	....	.....	....	...	...	...
Kew	"	none	none	none	....	.....	....	...	...	...
		17 15.8	17 16.4	17 17.1	....	.....	....	25.0	30.5	26.0

Group B.

Baldwin.....	Dec. 30,	13 59.9	13 59.3	13 58.8	+1.0	— 5.4	—2.4	27	26	21
Agincourt.....	"	13 47.1	13 51.3	.....	+0.8	— 5.0	....	31	32	...
Cheltenham	"	13 59.2	13 55.6	indef.	+0.6	—12.4	....	24	23	...
Porto Rico	"	14 02.0	14 02.0	14 02.0	+0.5	Ind.	—3.8	Ind	efin	ite.
Falmouth	"	13 58.0	none	none	—0.5	.....	....	32	...	...
		13 57.2	13 57.2	13 60.4	....	.....	....	28.5	27.0	21

(No effect discernible at Kew, Val-Joyeux, Uccle, De Bilt, Wilhelmshaven, Munich, Copenhagen, Seddin, Pola, Helwan, Mauritius.

Group C.

Honolulu	Dec. 30,	17 52.0	17 55.0	17 51.0	+1.0	— 1.3	+3.4	24	26	32
Sitka	"	51.4	50.0	none	—0.8	— 1.5	....	21	18	...
Baldwin.....	"	54.9	50.4	17 51.4	—1.0	—17.0	—3.0	24	32	20
Agincourt.....	"	46.1	51.3	.....	—1.2	— 6.7	....	20	38	...
Cheltenham ...	"	50.0	48.0	17 51.0	—1.6	—17.3	+(?)	40	31	Ind
Porto Rico	"	51.0	53.0	51.0	—1.0	Ind.	+6.6	26	Ind	26
		17 50.9	17 51.3	17 51.1				25.8	29.0	26.0

No effect discernible at Falmouth, Kew, Val-Joyeux.)

Group D.

Honolulu	Dec. 30,	18 61.8	18 55.0	18 59.0	+1.2	— 2.5	+4.2	33	35	36
Sitka	"	49.4	47.0	none	—0.8	— 2.0	....	36	38	...
Baldwin.....	"	58.9	57.4	18 57.6	—1.4	—20.6	—3.4	42	45	41
Agincourt.....	"	51.3	50.2	.....	—1.7	— 6.7	....	38	35	...
Cheltenham	"	57.5	54.5	18 56.0	—1.7	—14.2	+4.0	42	39	Ind
Porto Rico	"	61.3	60.7	59.3	—1.3	Ind.	+7.1	54	Ind	40
		18 56.7	18 54.1	18 58.0				40.8	38.4	39.0

III; and Table No. VI contains these quantities for six-minute intervals during the disturbance of December 29, 1908, at the Coast and Geodetic Survey Magnetic Observatories. ΔZ is given direct from the Z curve, ΔX and ΔY being computed from the ΔD and ΔH by the following relations:

$$\Delta X = \cos D\Delta H - H \sin D \sin 1'\Delta D. \qquad (1)$$

$$\Delta Y = \sin D\Delta H + H \cos D \sin 1'\Delta D. \qquad (2)$$

For convenience of comparison ΔX, ΔY, and ΔZ, at time of maximum are also given in this table.

Table VII contains some additional data obtained after the previous tables had already been prepared.

Coast and Geodetic Survey,
Washington, D. C., December 5, 1910.

ON A VARIATION IN THE INTENSITY OF THE PENETRATING RADIATION AT THE EARTH'S SURFACE OBSERVED MAY 19 and 21, 1910.[1]

By Arthur Thompson, M. A.

Since the discovery in 1902 of the penetrating radiation which exists at the surface of the Earth, a number of investigators have attempted to ascertain whether the radiation had its origin in the rocks and soil of the Earth or in the atmosphere of the latter, or whether it had its origin in one or more of the extra terrestrial bodies, such as the Sun or the Moon.

A number of investigators, including Borgmann,[2] Mach and Rimmer,[3] Wood and Campbell,[4] McKeon,[5] Strong,[6] Pacini,[7] and Wulf,[8] found in their various localities daily variations in the intensity of this radiation, and were able from their results to point to regular daily periods of maximum and minimum intensity. Further, an examination of the results of these investigators shows that the variation in the intensity of the radiation covers an exceedingly wide range.

In some cases variations of 10% from the normal intensity were observed, but in the majority of cases variations very much greater than this amount were commonly noted.

From a closer examination of the various results recorded, however, it does not appear that it is possible to establish any connection between the times of maxima and minima intensities obtained in different localities and, as a consequence, one is forced to the conclusion that the variations observed by them were due to local causes and not to any influences arising from the proximity of the Sun or any of the other celestial bodies.

The results obtained by Prof. McLennan and his students at Toronto, when investigating this penetrating radiation, have been quite different from those obtained elsewhere in that they failed to show the marked variations observed by others. In particular

[1] Communicated to the American Physical Society by Professor McLennan at the Minneapolis meeting, December 30, 1910.

[2] Borgmann, *Sc. Abstracts*, 1905, No. 1580. [3] Mach & Rimmer, *Phys. Zeit.* 7 pp. 617, Sept. 15, 1906. [4] Wood & Campbell, *Phil. Mag.* Feb. 1907. [5] McKeon, *Phys. Rev.* 1907. [6] Strong, *Phys. Rev.* July, 1908. [7] Pacini, *Rend. All. Lincei*, 18, 123–129, 1909. [8] Wulf, *Phys. Zeit.* 10, 1909, 152–157.

C. S. Wright, who made a number of observations at Toronto, was not able to find any appreciable regular variation in the intensity of the penetrating radiation, and the variations which he did observe did not exceed 3% of the observed normal intensity of the radiation.

These observations were confirmed later by G. A. Cline, and the conclusion was drawn by both these investigators that the soil contributed by far the greater proportion of the penetrating radiation present at the Earth's surface at Toronto, and that any portion which might be contributed by the Earth's atmosphere or by the Sun was negligible in comparison with that arising from the soil.

The view that the soil was the chief source of the radiation was corroborated later by the discovery of Prof. McLennan and C. S. Wright that the intensity of the radiation was very much less over the surface of Lake Ontario than over the surface of the land adjoining the waters of the lake.

This diminution in the intensity of the radiation over lake waters was also observed later by Gockel at Vierwaldstättersee in Switzerland.

From these experiments it seems then that there is no doubt about the soil and rocks of the Earth being the chief source of the radiation. It appears too that the atmosphere of the Earth contributes but a small proportion, if any, of the radiation. There is, moreover, no evidence to show that any part of it has its origin in either the Sun or the Moon.

Although it is clear from the evidence adduced above that it is not possible to ascribe an appreciable proportion of the penetrating radiation as ordinarily observed to a celestial origin, it seemed possible that the intensity of the radiation might be increased by the passage near to the Earth of a body possessing the constitution and characteristics of Halley's Comet. And, at the suggestion of Prof. McLennan, the writer undertook to make a series of observations on the intensity of the radiation extending over a number of days during the period when the comet and its tail was predicted to be in closest proximity to the Earth.

To make the observations, an ionization vessel of about 30,000 ccs. capacity, similar to that used by C. S. Wright, and later by G. A. Cline, was installed on the roof of the Physical Laboratory, and readings on the conductivity of the air in the vessel were taken

with a sensitive quadrant electrometer situated in a room directly below the point where the ionization vessel was installed.

In setting up the apparatus the most extreme care was taken to see that all insulating parts were clean and dry, that the receiver itself was hermetically sealed, and that all electrical connections were effectively and thoroughly screened.

The observations were begun on the morning of May 18th, and were continued without interruption until noon on May 21st. The results of these observations, expressed as the number of ions made per cubic centimetre per second in the ionization chamber, are represented by a curve shown in Fig. 1. From the numbers given it will be seen that while the normal ionization was about 30 ions per cc. per second, two rather remarkable increases were noted in the observed ionizations. One of these occurred on May 19th, beginning at 1 o'clock P. M., and lasting until about 4 P. M., and the other on May 21st, commencing at about half past nine in the morning and continuing for a period of about one hour and a half. On these two occasions it will be seen that the ionziation rose to about 100 and 130 ions per cc. per second respectively. [Throughout this paper, the times given refer to 75th meridian mean time.]

Whether these unusual increases in the ionization were due to the presence of the comet or not, it appears to the writer impossible to decide. A. Wigand,[9] in a paper on observations made at Halle, from May 17th to May 20th, records decided diminutions in the Earth's horizontal magnetic field during the early hours of May 19, and again from 7:36 to 11:30 A. M. of the same day. He also records a marked increase in the electrical conductivity of the atmospheric air between the hours of five and nine o'clock on the morning of May 19th, and at the same time an anomalous depression in the potential gradient. Wigand concludes from his observations that these magnetic and electrical disturbances were in all probability connected with the passage of the comet.

The disturbances noted by Wigand, it will be seen, took place on May 19th at 11 A. M., about 12 hours before the one at Toronto occurred. The phenomena observed by him were the electrical "dissipation" and the potential gradient, while that investigated by the writer was the ionization in the gas within an hermetically closed metallic vessel. It is possible to conceive that three such phenomena could be related, but in the present case it is difficult to see any

[9] WIGAND, *Deutsche Phys. Ges. Verh.* 12, 13, pp. 511-530, July 15, 1910.

connection between the two sets of disturbances noted, and still more difficult to establish a connection between them and the passage of the comet.

To the writer there appear to be four possible explanations of the disturbance noted by him. It could in the first place be caused by bringing radioactive bodies into the neighborhood of the ionizing chamber. It might also be produced by temporary faulty instrumental conditions or adjustments. Then again the disturbance might be the result of some intense temporary solar activity, or finally it might be due to the passage of the comet. The first explanation can be easily dismissed, for no radioactive bodies were brought near at any time while the observations were being taken. In regard to the second explanation, it may be stated that extreme care was taken to perfect the conditions of measurement. Even after the measurements were finished the whole instrumental outfit was again closely scrutinized, but a rigid examination failed to reveal any faulty adjustment.

The writer is therefore inclined to the view that the disturbance was not due to faulty conditions of experiment or to faulty adjustments.

With the object of corroborating this view, observations were again made for periods of about twelve hours on May 23d, 24th, 25th, and 26th. The results of these are illustrated by a curve given in Fig. II. These observations, it will be seen, failed to show anything abnormal. The ionization varied between narrow limits, and the observations were practically of the same character as those made by Wright and Cline on previous occasions.

If the disturbance noted were due to faulty adjustments or to some cause associated with the Sun's activity, one would expect a repetition of the disturbance. None such occurred, however, during any of the four later periods of observation, and this absence of a repetition would go to confirm the view that the disturbance was not due to any defect in the measuring apparatus.

The absence of a repetition on the four days mentioned, however, would not entirely exclude solar activity as a cause of the disturbance. To establish this point it would be necessary to make a more extended series of observations.

All the readings recorded in the present paper were taken visually, but the strain of making measurements in this manner over long continued periods of time is too great for continued visual ob-

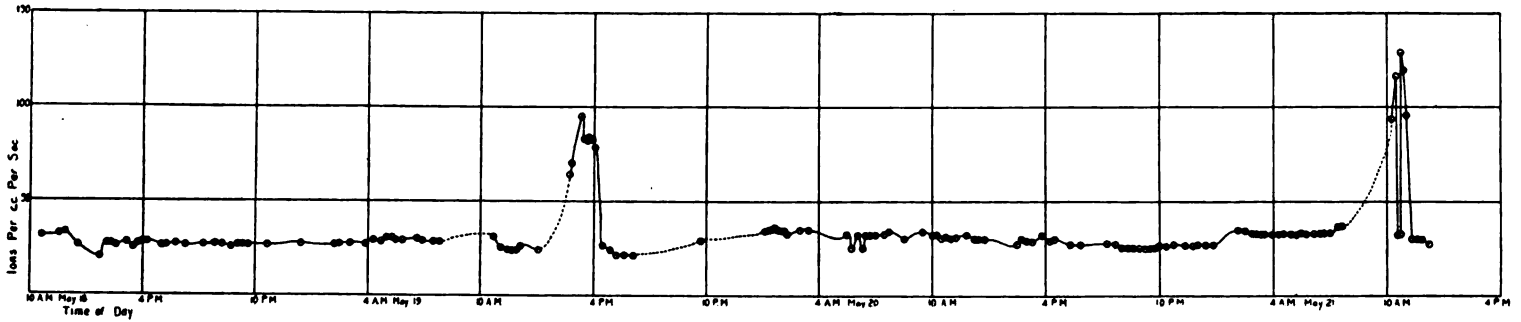

Ions Per c.c. Per Sec.
Time of Day
10 A.M. May 18
4 P.M.
10 P.M.
4 A.M. May 19
10 A.M.
4 P.M.
10 P.M.
4 A.M. May 20
10 A.M.
4 P.M.
10 P.M.
4 A.M. May 21
10 A.M.
4 P.M.

Fig. I

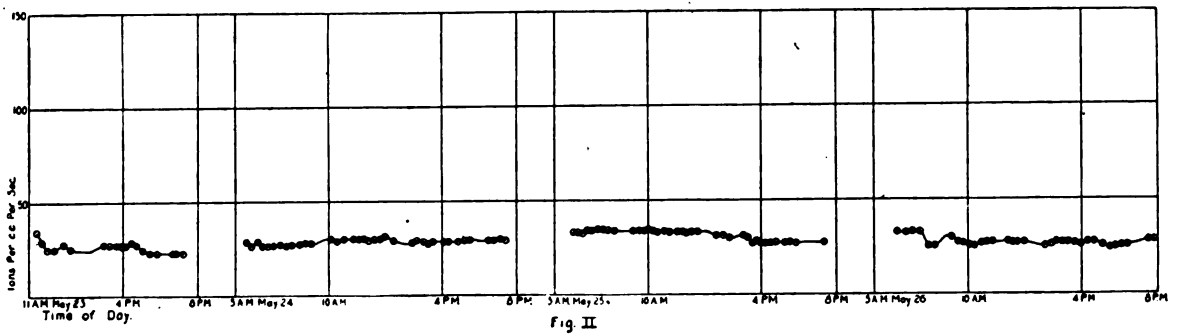

Ions Per c.c. Per Sec.
Time of Day.
11 A.M. May 23
4 P.M.
8 P.M.
5 A.M. May 24
10 A.M.
4 P.M.
8 P.M.
5 A.M. May 25
10 A.M.
4 P.M.
8 P.M.
5 A.M. May 26
10 A.M.
4 P.M.
8 P.M.

Fig. II

servations to be practicable, and the writer therefore hopes to continue, at an early date, the observations with self-recording apparatus with a view to seeing whether solar activity is ever really accompanied by such terrestrial disturbances as those noted, or not.

This information would be useful in deciding between solar activity and the comet's influence as the cause of the disturbance.

In conclusion, the writer wishes to acknowledge his indebtedness to Prof. McLennan for suggestions during the investigation, and for his kindness in scrutinizing the installation of the apparatus, and also to Mr. W. T. Kennedy for his kind assistance in taking some of the readings.

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LE PROJET DU LEVÉ MAGNÉTIQUE DE L'EMPIRE RUSSE ET LES TRAVAUX MAGNÉTIQUES EXECUTÉS EN RUSSIE EN 1910.

PAR M. RYKATCHEW.

Dans mon rapport à la Commission magnétique du Comité Météorologique International, publié dans le Rapport de cette Commission,[1] j'ai communiqué le plan du levé magnétique de l'Empire Russe, projeté par la Commission Magnétique, nommée près de l'Académie Impériale des Sciences de St. Pétersbourg. Cette Commission consiste des représentants de l'Académie des Sciences, de l'Observatoire Physique Central Nicolas, des différents ressorts et Institutions, des Sociétés scientifiques, des Universités et des autres établissements et personnes privées, qui ont bien voulu prendre part à l'entreprise.

Le projet du levé magnétique avec le devis a été présenté à l'Académie, laquelle dans sa séance du 13/26 octobre l'a approuvé. Desirant faire tout ce qui est dans son pouvoir pour soutenir cette entreprise elle a decidé d'assigner de son côté pour le levé magnétique 10,000 rb. par an depuis 1912 durant 10 années si elle reçoit le crédit qu'elle demande pour les entreprises scientifiques de l'Académie. Ce don considérable et la bonne volonté des autres institutions et personnes, qui voulent bien prendre part dans nos travaux, nous donne l'espoire que nous parviendrons au but.

En attendant d'accord avec la résolutions prise par la Commission les participants font ce qu'ils peuvent avec les moyens qu'ils ont.

Voici les travaux executés en Russie en 1910 pour le levé magnétique.

Les observateurs de l'Observatoire Constantin ont fait les observations magnétiques sur 73 points dans la gouvernement de St. Pétersbourg, maintenant la distance prescrite à peu près de 20 verstes (21 kilom.). Nous pouvons regarder provisoirement que le levé de ce gouvernement est executé. Les calculs sont achevés, et les resultats seront bientôt publiés; mais sans réduction à quelque époque donnée. Cette réduction à la moyenne de 1910 sera faite aussitôt que l'exacte valeur de cette moyenne sera calculée.

Trois observateurs, instruits préalablement à l'Observatoire Constantin, ont été expediés par le Département Hydrographique du Ministère de la Marine pour faire les observations magnétiques aux bords du golfe de Finlande et de la mer Noire. Le nombre total des points déterminés par eux est 89.

[1] Bericht über die Versammlung des Internationalen Meteorologischen Komitees und dessen Kommission für Erdmagnetismus und Luftelektrizität. Berlin, 1910, Anhang IX an Protokolle der Sitzungen d. Magnetischen Kommission, Berlin, 23-24 Septembre 1910, p. 96.

Le général-major Jdanko, chef de l'expédition hydrographique, a fait des observations sur 21 points à bord de l'ocean Pacifique.

Deux observateurs sous la direction de M. le professeur Weinberg de l'Université de Tomsk ont déterminé les éléments magnétiques sur 50 points dans la région d'Altay et dans la partie centrale de Siberie.

M. Goultiaev, le chef de la section météorologique de l'Observatoire Astro-physique à Tachkent, a fait plusieurs observations en Tourkestan et dans la province Semiretchenskaya.

M. Stankewitch, le professeur de l'université à Odessa, a expedié 2 personnes qui ont fait des observations sur 21 points dans les gouvernements de Kalouga et de Smolensk et sur 4 dans le gouvernement de Kherson.

M. Kalinovsky, attaché au Musée d'Industrie et d'Agriculture à Warsovie, a communiqué à notre commission magnétique qu' à cause de sa maladie il n'a pu faire que 9 stations magnétiques jusqu'au mois de septembre; il esperait augmenter durant l'automne ce nombre jusqu'à 30.

Du rapport de M. Melander publié dans l'annexe VIII aux Procès Verbaux de la Commission magnétique Internationale,[1] on voit qu' en Finlande les travaux le levé magnétique sont organisés tout à fait d'accord avec le plan élaboré par notre Commission Magnétique. Le crédit necessaire est assigné pour achever le levé magnétique dans 10 ans à peu près. En 1910 M. Hintikka, l'assistant de M. Melander, a determiné les coefficients de ses instruments à Pavlovsk et determiné les éléments magnétiques sur 14 points en Finlande.

Ont été publiés en 1910: Les observations magnétiques faites par M. Smirnov entre Warsovie et Wladivostock en 1901, 1904 et 1902;[2] les resultats de la comparaison des instruments de l'Observatoire Constantin à Pavlovsk avec ceux des observatoires; à Karsani (près de Tifliss), à Ekaterinbourg, à Irkutsk, à Upsala, à Rud Skov et à Potsdam. Ces resultats sont publiés dans le Rapport mentionné du Comité Météorologique International (Berlin 1910. Anhang IV, p. 88.).

Durant l'année 1910 les magnétographes ont continué à fonctionner régulièrement à Pavlovsk, Tifliss, Ekaterinbourg et Irkutsk, Les resultats jusqu'à 1907 inclusivement sont publiés. Ceux de 1908 sont sous presse.

[1] Bericht über die Versammlungen des Internationalen Meteorologischen Komitees und dessen Kommission für Erdmagnetismus und Luftelektricität. Berlin, 1910, p. 94.

[2] D. A. SMIRNOV. Die Magnetische Elemente auf der Linie von Varschau bis Vladivostok nach den Beobachtungen von 1901, 1904 und 1909. *Bulletin de l' Académie Imp. des Sciences de St. Pétersbourg*, 1910.

THE PHYSICAL THEORY OF THE EARTH'S MAGNETIC AND ELECTRIC PHENOMENA.—No. III.

By L. A. Bauer.

THE EXTERNAL ELECTRIC CURRENTS AND THE EARTH'S MAGNETIZATION.

26. The hypothesis of ionic currents employed in the study of the magnetic disturbances thus far treated was based on the existence of a primary electric field. Quoting from No. I, § 11:

> Since magnetic observations made at various points on the Earth's surface have revealed the existence of a definite system of atmospheric electric currents, it follows at once that if the atmosphere is made more conducting at any point, an extra current will be started and set in motion by the pre-existent electromotive force or its equivalent. The direction followed by the new current depends upon its origin, upon the direction of the electromotive force at that point, and upon the deflecting effect of the Earth's magnetic field and of the Earth's rotation on the electric carriers. In other words, while we shall look chiefly to extra-terrestrial agencies for ionizing the air and thus splitting it up into carriers of positive and of negative charges, we look to the atmospheric electric field and to the Earth's rotation for furnishing the energy necessary to drive the ions over the Earth and by their motion produce the effects observed during a magnetic storm.

It concerns us greatly, therefore, to find out all we can as soon as possible regarding this external electric field. And here is where the great value of the extensive magnetic operations of the Carnegie Institution of Washington will be demonstrated; for the precise characteristics of that outside electric field can not be accurately determined until the completion of a general magnetic survey of the globe. When that has been accomplished, which we hope will be the case within the next five to ten years, then the constants, or rather the determining coefficients, can be derived for the various constituent portions of the Earth's total magnetic field.

In the meanwhile such data must be used as are available; in view, however, of their possible inaccuracy (*Cf.* PD III b, *Terr. Mag.*, v. 8, 1903, pp. 118-128), only general characteristics can at present be given.

27. Table IX, taken with slight modifications from my paper PD V, p. 179, gives the results of the analyses to date. I have confined myself, for the present, chiefly to the first harmonic coefficients which represent the "uniform" portions of each field, i. e., the term corresponding to a simple magnetization of the Earth

(Internal System) and of the atmosphere (External System) each about a certain diameter, so that the magnetic poles for each field are diametrically opposite each other. The other harmonic terms show the atmosphere's system to be as complex as the Earth's, but owing to our incomplete knowledge of the actual distribution of the magnetic forces over the Earth's surface, their accurate determination is at present beset with considerable difficulties. Even for the three principal coefficients given, the differences between the results of various analysts for the same year are greater than desirable. Each column, as is seen, gives the name of the investigator who made the analysis and the year for which it applies. The quantities are expressed in gammas ($\gamma = 0.00001$ C. G. S. Unit). The same notation is used as for Table I.

Looking first at the values of ϕ_n and λ_n, which are the latitude and longitude, respectively, of the point of intersection in the Northern Hemisphere of the magnetic axis with the surface, or in other words, of the North Magnetic Pole, a satisfactory agreement is found between the results of the various analyses, except for the *A* system of Adams, 1830, which for some reason stands out from the rest; omitting the latter and combining the results for each epoch 1843 and 1885, the last two columns of the table are obtained. Strictly speaking, since the secular change is not linear, it is only admissible to combine the results for two such distant years as 1843 and 1835 if merely general results are to be derived. However, the error committed by taking the mean is doubtless no greater than the uncertainties of the present figures themselves. We accordingly have[1]:

Geographical Co-ordinates of North Magnetic Pole for Primary Systems.

(Approximately for the year 1864.)

	Earth's Magnetic System.	Atmosphere's Magnetic System.
Latitude, ...	78°36′N	59°30′N
Longitude, ...	66 29 W	153 51 W

It is thus seen that the North Magnetic Poles of both systems are in the Northern Hemisphere, hence the magnetizations in both cases are directed alike. Furthermore it will be noted that the North Magnetic Pole of the atmospheric field is west and south of that of the Earth. By "North Magnetic Pole" is, of course,

[1] The reader should bear in mind that these positions of the poles only refer to the portion representable by a uniform or simple magnetization.

Table IX. Uniform Portion of the Primary Magnetic Systems of the Earth and of the Atmosphere.

QUANTITY	EARTH'S MAGNETIC SYSTEM							ATMOSPHERE'S MAGNETIC SYSTEM							Mean of 1843 and 1885	
	Adams 1843	Fritsche 1843	Adams 1880	Fritsche 1885	Schmidt 1885	A. & F. 1843	F. & S. 1885	Adams 1843	Fritsche 1843	Adams 1880	Fritsche 1885	Schmidt 1885	A.& F. 1843	F. & S. 1885	Earth	Atmosphere
$-g_{10} = M_p / R^3$	$\overset{\gamma}{+32146}$	$\overset{\gamma}{+32215}$	$\overset{\gamma}{+31696}$	$\overset{\gamma}{+31537}$	$\overset{\gamma}{+31733}$	$\overset{\gamma}{+32169}$	$\overset{\gamma}{+31635}$	$\overset{\gamma}{+185}$	$\overset{\gamma}{+237}$	$\overset{\gamma}{-24}$	$\overset{\gamma}{+237}$	$\overset{\gamma}{+186}$	$\overset{\gamma}{+202}$	$\overset{\gamma}{+212}$	$\overset{\gamma}{+31902}$	$\overset{\gamma}{+208}$
$-g_{11}$	+2778	+2725	+2411	+2392	+2356	+2760	+2374	−24	−25	−119	−165	−241	−17	−203	+2567	−110
$-h_{11}$	−5789	−5899	−6017	−5965	−5984	−5826	−5974	−145	−148	+147	+73	+3	−146	+38	−5900	−54
M_e / R^3	−6421	−6498	−6482	−6427	−6431	−6447	−6428	−147	−150	+189	+180	+241	−147	+207	−6434	−123
M / R^3	+32782	+32863	+32356	+32186	+32378	+32809	+32282	+236	+281	+191	+298	+304	+250	+296	+32545	+242
Φ_n	78 42.3 N	78 35.8 N	78 25.0 N	78 28.8 N	78 32.6 N	78 40 1 N	78 30.8 N	51 5 N	57.6 N	7.2 S	52.7 N	37.7 N	53 9 N	45 8 N	78 36 N	59 30 N
λ_n	64 22 W	65 12 W	68 10 W	68 09 W	68 31 W	64 39 W	68 20 W	99.4W	80 4 W	231.0W	203.9 W	180.7 W	92.6W	190 6 W	66 29 W	153 51 W

meant the Pole which attracts the north-seeking end of a magnetic needle. If we pass a great circle through the two positions it is found that the magnetic axis of the atmosphere's system is displaced from that of the Earth's through an angle of 31°.9, mainly to the westward.[1]

There is this essential difference between the magnetic systems of the Earth and of the atmosphere, viz., that while their North Magnetic Poles are both in the Northern Hemisphere, that of the Earth is below the surface, whereas that of the Atmosphere is in the regions above; hence, while the effects on the compass needle are the same for both, the effects on the dip needle are opposite. The Earth's system makes the north-seeking end of the needle dip below the horizon in the Northern Magnetic Hemisphere, whereas the magnetic system of the Atmosphere, were it alone acting (the Earth's being eliminated), would make the north-seeking end of the needle point above the horizon. Hence the effects of the two systems on the vertical magnetic component are opposite in the same hemisphere. The compass charts, however, show the same general characteristics for both in each hemisphere.

28. *How may the magnetic systems of the Earth and of the Atmosphere, just described, have been brought about?* Let us assume that there are negative electric currents circulating overhead around the Earth, lying approximately on a spherical surface and proceeding in a generally eastward direction, so that were we looking down upon them in the direction of the North Geographical Pole, we should find them going around anti-clockwise. Or, were we looking along the axis of the Earth in the direction from South to North, then the assumed negative electric currents would be seen circulating clockwise, or the equivalent positive currents, anti-clockwise. We thus have a spherical solenoid; let us suppose at first the Earth to be removed from within it. Applying the well-known rules[2] to the

[1] Schuster's statement in *Terr. Mag.* v. 1, p. 16, that the outside magnetic potential is displaced towards the east, should read towards the *west*, as he has recently informed me, thus agreeing with my statement.

[2] Quoting, for example, from SYLVANUS P. THOMPSON'S *Elementary Lessons in Electricity and Magnetism*, 1902, pp. 375-376: "Looking at the S-seeking pole of an electromagnet, the magnetizing currents are circulating round it in the same cyclic direction as the hands of a clock move; and, looking at the N-seeking pole of an electromagnet, the magnetizing currents are circulating round it in the opposite direction to that of the hands of a clock." It must be recalled that this statement applies to positive electric currents and the rules would accordingly have to be reversed for negative currents.

supposed solenoid, the north-seeking end of our electro-magnet would be south. Hence were we to suppose the Earth, initially unmagnetized, to be back inside the solenoid, and assume, as we apparently may, that it acts chiefly as a paramagnetic substance, it would be magnetized by the hypothetical electric currents so that its north-seeking magnetic pole, or as we are accustomed to say, its "South Magnetic Pole," would lie in the Southern Hemisphere. The introduction of the paramagnetic substance serves chiefly to intensify the magnetic field due to the solenoid alone, and does not alter its direction.

The space between the Earth's surface and that of the solenoid, in accordance with what has already been said, would be magnetized in the same general direction as the Earth. The axis of magnetization of this outside field, since the magnetic permeability of air is practically unity or the same as a vacuum, will correspond to that of the solenoid without a core, except near the Earth itself, where certain disturbing influences due to the latter's field would make themselves felt. The magnetic axis of the Earth, however, will suffer an angular displacement dependent upon the magnetic permeability along different diameters, *i. e.*, whether or not the Earth acts like an isotropic or a crystalline substance; the displacement will also depend upon any previous magnetism which may exist inside the Earth. Hence, though the magnetizing cause be the same for both Earth and atmosphere, their magnetic axes need not necessarily be parallel, but we may expect them to be pointed in the same general direction if the Earth be paramagnetic.

It will be noticed that the core of our hypothetical spherical solenoid consists partly of the Earth and partly of the air. The Earth in turn is composed of a great many substances, both paramagnetic as well as diamagnetic, and these too existing in physical states such as we can not even approximate to in our laboratories. Thus, for example, we know that under ordinary conditions a magnetized substance loses its magnetism with application of heat. Applying this physical fact to the Earth, it can be shown that the magnetizable substances, according to Prof. J. A. Fleming, must all lie in a stratum which extends down from the surface only to a depth of about ten to twelve miles.[1] Dr. Bidlingmaier, by a similar computation, has recently found this limiting depth to be 20 to 26 kilo-

[1] FLEMING, J. A., "The Earth, a Great Magnet." *Terr. Mag.*, v. II, p. 57.

meters, or twelve to sixteen miles.[1] However, these calculations assume that pressure plays no part in the retentivity of magnetism. May it not be possible that the relatively more rapid increase in pressure than in temperature as the Earth is penetrated may also, as regards magnetism, annul in part at least the effect of the increased temperature? This we know to be the case with reference to the melting point of substances which are raised with increased pressure.

As a first approximation, we may regard the Earth as a ferric substance, so that the core of our supposed solenoid is roughly of the aero-ferric type. The heterogeneity of the ferric portion will afford abundant opportunity for the existence of such complex magnetizations as are actually exhibited by the Earth.

29. According to the view presented, the Earth's magnetization, while partially in a permanent state, would be primarily in a subpermanent or transient condition. *Until something better presents itself, the following working hypothesis is here adopted: The Earth is chiefly an electromagnet, the magnetizing currents being outside and consisting of negative electric currents circulating overhead in the same general direction as that of the Earth's rotation, namely, from west to east.*

Thus the magnetic state of our planet is put primarily in the control of outside electric currents; any change in their direction or strength must produce almost immediately corresponding magnetic changes in the Earth. Only in this way, it is believed, will it be possible to explain what it is that can derange the magnetization of our entire planet to the extent of ten to twenty per cent in the brief interval of a quarter of an hour, as actually occurred during the magnetic storm of September 25, 1909, the most notable of which we have any record. Referring to changes in the Earth's magnetism, insignificant alongside of those just mentioned, viz., the secular changes, which only reach a comparable amount when integrated over a period of several centuries, Maxwell says: "When we consider that the intensity of the magnetization of the great globe of the Earth is quite comparable with that which we produce with much difficulty in our steel magnets, these immense changes in so large

[1] Bidlingmaier, Fr., "Über das Wesen der säkularen Variation des Erdmagnetismus, und Bestimmung ihres Ursprungsortes im Erdinnern." *Physik. Zs.*, Leipzig, Vol. XI, 1910, pp. 1216–1222. A discussion of other points in Bidlingmaier's theory of the secular variation of the Earth's magnetism has been sent by me to the "Physikalische Zeitschrift."

a body force us to conclude that we are not yet acquainted with one of the most powerful agents in nature."

It is generally assumed that the method of analysis first applied to the Earth's magnetic state by Gauss, and since then extensively followed, settles the question that the magnetizing causes must for the greater portion (about 95% according to Adolf Schmidt's figures) be contained within the Earth itself. This, however, is not necessarily true. As has been shown above, it is possible to magnetize the Earth by outside currents in precisely the manner we actually find it to be. When dealing with a solenoid we most often have in mind a cylindrical core, the equivalent magnetic poles of which lie somewhere near the ends. For a spherical core, however, the equivalent magnetic poles, as far as external magnetic effects are concerned, are practically both at the center. As is well known, the external action of a uniformly magnetized sphere is the same as that of an infinitely short magnet having the same magnetic moment and same direction of magnetic axis. It might be said that the effect of a spherical core is to suck down into it the magnetic poles of the solenoid, a set of external lines of magnetic force thus resulting which are precisely the same as though the Earth had been magnetized by internal forces. The extent of this sucking in or the extent to which the external lines of magnetic force will approach those of a uniformly magnetized sphere or of some other body, *e. g.*, that of a cylinder, will depend more or less upon the orbits of the external electric currents. Variations in these orbits, aside from intensity changes, will be accompanied by surgings up and down in the Earth's magnetic lines of force. Whether it will be possible to explain some of the phenomena of polar lights in this manner is reserved for future consideration.

Is the Earth an Electromagnet?

30. It will be helpful to have a definite picture of the internal and external lines of force of a uniformly magnetized sphere. For simplicity, let us suppose that the Earth is magnetized uniformly about the axis of rotation so that the so-called North Magnetic Pole, having the same kind of magnetism as that of the south-seeking end of a compass, and designated by NM in Fig. 1, is coincident with the Geographic North Pole. I am indebted to Prof. H. W. Fisk, my assistant, for the construction of the diagram. The arrows as drawn give the direction taken by a magnetic needle used

to explore the field. From the statements usually found in text books with regard to the magnetic circuit—that the directions inside and outside are opposite—the conclusion might be drawn that while outside the compass points north, inside its direction is, in general, reversed. A little reflection will immediately show that this can not be the case. For example, at the point E on the equator, if the

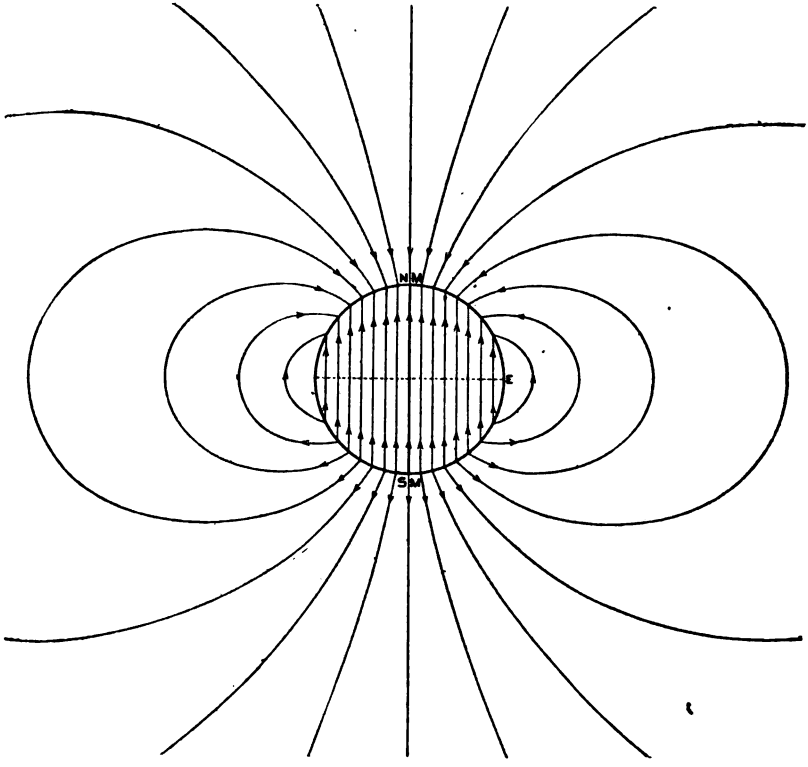

FIG. 1. *Lines of force of a uniformly magnetized sphere.*

lines of magnetic force, inside and outside, were reversed in direction, the resultant magnetic force would be zero or nearly so, but this we know not to be the fact. The horizontal component of the Earth's magnetism is a maximum near the equator, and reaches a value about one-half that of the total intensity at the Poles. We must assume the internal line of force to be non-existent, or diminished in strength, or finally that it is directed the same way as the outside one, as shown in the diagram. As the lines

of magnetic force break through the surface they suffer a displacement. These statements will be clearer from the equations.

Let the axis of rotation which, for the case supposed, is likewise the axis of magnetization, be the Ξ axis of a system of rectangular coordinates, with the origin at the center of the Earth. Let R be the Earth's mean radius, r the radius vector to some point, P, and ρ the intensity of magnetization per unit volume. Then the magnetic potential V_0, at any point outside the sphere will be:

$$V_0 = \frac{4}{3}\pi\rho\, R^3 . \frac{\xi}{r^3} \quad ; \qquad (1)$$

and for a point within:

$$V_w = \frac{4}{3}\pi\rho\, . \xi \quad . \qquad (2)$$

For polar coordinates (u, r), u being the angle which the radius vector makes with the axis, counted from the North Pole continuously through the equator to the South Pole:

$$V_0 = \frac{4}{3}\pi\rho\, R^3 . \frac{\cos u}{r^2} \quad , \qquad (3)$$

$$V_w = \frac{4}{3}\pi\rho\, . r \cos u \quad . \qquad (4)$$

If we take next a local system of coordinates, X, Y, Z, of which X is directed along the meridian positive towards the North, Y positive to the geographic east, and Z, the vertical component counted positive downward, then by partial differentiation of (3) and (4) there results, remembering the sense in which the variables increase:

For a point outside the sphere:

$$X_0 = -\frac{4}{3}\pi\rho\, R^3 . \frac{\sin u}{r^3} \quad , \qquad (5)$$

$$Y_0 = 0 \quad , \qquad (6)$$

$$Z_0 = -\frac{8}{3}\pi\rho\, R^3 . \frac{\cos u}{r^3} \quad . \qquad (7)$$

For a point within the sphere:

$$X_w = -\frac{4}{3}\pi\rho\, . \sin u \quad , \qquad (8)$$

$$Y_w = 0 \quad , \qquad (9)$$

$$Z_w = +\frac{4}{3}\pi\rho\, . \cos u \quad . \qquad (10)$$

Comparing (5) and (8) it is seen that for the same hemisphere the component X, has the same direction whether the point, P, be outside the sphere or inside; however, the vertical component, Z, as seen from equations (7) and (10) is of opposite sign, inside and outside.

31. If P be on the surface $r = R$, and we have:

$$X_s = -\frac{4}{3}\pi\rho \cdot \sin u \quad , \tag{11}$$

$$Y_s = 0 \quad , \tag{12}$$

$$Z_{o,s} = -\frac{8}{3}\pi\rho \cdot \cos u \quad , \tag{13}$$

$$Z_{w,s} = +\frac{4}{3}\pi\rho \cdot \cos u \quad . \tag{13a}$$

The quantity $-\frac{4}{3}\pi\rho$ is the same as our $-g_{10}$ in Table IX, viz., for the Earth +.319 C. G. S. (next to last column, first line). Substituting we get:

$$X_s = +.319 \sin u \; ; \; Z_{o,s} = +.638 \cos u \; ; \; Z_{w,s} = -.319 \cos u \; . \tag{14}$$

Thus at the equator, where $\sin u = 1$, the component which tends to set a compass needle with its north-seeking end north, is +0.319 C. G. S. unit whether the point be at an infinitesimal distance below or above the surface; if a surface electric current were circulating along the equator, then the direction of a compass needle ought to be reversed, as it is passed from a point above the current to a point below. Accordingly a spherical magnet for a point near the equator presents, apparently, a contradiction to Ampère's well-known rule.

For the equator, since $\cos u = 0$, $Z_s = 0$. Turning next to the North Pole, $\sin u = 0$ and $\cos u = 1$, hence:

$$X_s = 0 \; ; \; Z_{o,s} = +.638 \; ; \; Z_{w,s} = -.319 \; . \tag{15}$$

For a point at an infinitesimal distance above the Pole the Z component will be a trifle less than +.638, but for a point at the same distance below, it suddenly changes to —.319 C. G. S. (*Cf.* equations 7 and 10). Here then there is a reversal in the component acting on the north end of the needle as we pass from one side of the surface to the other; Ampère's rule is fulfilled and we find that looking down on the North Pole, positive currents would have to circulate clockwise, or negative ones anti-clockwise, precisely as do the currents in section 28.

32. The apparent contradiction of Ampère's rule, as above pointed out, is due to the complex conditions introduced by a spherical magnet—outside, a magnetic needle sets itself obedient to the lines of magnetic force which would result from an infinitely short magnet, and inside, as though the poles were at an infinite distance apart. It must be remembered also that the systems of coordinates generally used change with locality. Referred to the system used in equations (1) and (2) X at the equator is the same as Ξ, and at the North Pole, $-Z = \Xi$; referred to the local systems X and Z would be perpendicular to each other. It is the neglect of these facts that has brought about the confusion to which I myself, in common with others, have contributed, and which has retarded progress.

Thus, to quote from the paper presented before the International Electrical Congress, held at St. Louis in 1904[1]:

> One of the most fundamental inquiries to be made in the discussion of any of the Earth's magnetic phenomena, before attempting a theoretical explanation, is as to the seat of the forces giving rise to the phenomenon in question. Thus many a theorist might have saved himself some pains had he first addressed himself to this inquiry. To illustrate:
>
> Suppose our first question to be the following: Since we can produce the magnetic phenomena pertaining to the Earth's so-called "permanent" magnetism, observed on the surface, by a system of closed electric currents, where are these currents? Do they circulate around the Earth below the surface or in the regions above us? We know, as a fact of common experience, that the end of the needle designated as the north-seeking end, or for short, the north end, points approximately towards the north. Hence, applying Ampère's rule, the electric currents necessary to produce this phenomenon must circulate around the Earth from east to west, if they be inside the Earth, and if on the other hand, outside the Earth, they must circulate from west to east. To determine where the currents really are we must resort to another well-known phenomenon, viz., that the end of the needle which points to the north dips below the horizon in our hemisphere and points above the horizon in the southern magnetic hemisphere. Applying to this phenomenon Ampère's rule, we shall find that the currents can only circulate from east to west; hence combining this deduction with our previous one. the answer is that the electric currents which are capable of producing the observed magnetic phenomena cited circulate from east to west inside the Earth.

The fallacy in the above argument will now readily be seen. The phenomena of the compass needle in the equatorial regions and of the dip needle in the polar localities are not different facts, but essentially the same—the apparent difference is simply due to

[1] *Science*, N. S., v. XX, No. 515, Nov. 11, 1904, p. 635.

the shift of our local system of coordinates from the equator to the Pole. Then again be it observed that in going from a point on the equator, where we would be outside or above an electric current imbedded within the Earth, to the Pole we are now inside or below a current circulating around a polar parallel of latitude, irrespective of whether that current be inside the Earth or outside. The argument in the above quotation is accordingly doubly fallacious; not only has our system of coordinates been shifted through 90° in going from the equator to the Pole, but our relation, whether above or below, with reference to any possible system of electric currents has also been changed. Hence extreme caution must be used in deducing the direction of an electric current from the observed magnetic phenomena over but a limited portion of the Earth. Errors of this kind are found in Birkeland's investigations to which we shall return further on.

33. It is important to note that if Ampère's rule be applied to the magnetic phenomena at the North Pole, where, for the simple magnetization considered, the dip needle would stand vertical with the north-seeking end down, only the direction of the electric currents is fixed—east to west if positive and the reverse for negative. As to the seat of the currents, whether or not they be below the Earth's surface, nothing is definitely determined. Accordingly the general magnetization of the Earth is such that if caused by negative currents they must go from west to east or in the same direction as the Earth's rotation, whether in the atmosphere above or in the Earth below. The fixing of this fact is regarded as an important advance. Heretofore it has been universally thought that the currents would have to go in opposite directions, if above or below.

How can we determine the actual seat of the negative electric currents? If they are wholly within the Earth then the magnetic components at all points on the surface must correspond to the laws of the external lines of magnetic force of a spherical magnet (equations 1, 3, 5, 6, 7). If some are circulating overhead then there must be, in addition, components which comply with the laws of an internal system of lines (equations 2, 4, 8, 9, 10). The results of the analyses of the Earth's total field, given in Table IX. reveal effects from both systems; hence, certainly some of the electric currents, at least, must be in the regions above us. This must be regarded as one of the chief results of the Gaussian method of analysis.

Since, then, it appears absolutely necessary to have some aerial electric current system, the question next arises: Is it possible to assume that the greater portion at least of the electric currents are circulating above and can we thus account for nearly all of the magnetic systems disclosed by observation on the Earth's surface? The answer to this hinges chiefly on the Earth's magnetic permeability.

34. If we suppose that the constants of the external or atmospheric field as derived from magnetic observations on the Earth's surface represent truly the external magnetizing currents, it would be possible to obtain some approximate idea at least, of *the Earth's average magnetic permeability.* The magnetic moment of the Earth's total magnetic system is to that of the atmosphere's approximately as 32,750: 242, or as 135: 1, so that, under the conditions supposed, the Earth's magnetic permeability would have to be on the order of about 135, as referred to air, for a magnetizing force of about 0.0024 C. G. S.

This value, though large, is not impossible. Thus from C. Baur's[1] experiments on a ring of soft iron for small magnetizing forces there resulted a linear formula for the magnetic permeability:

$$\mu = 183 + 1382\,H \quad ;$$

$$\text{hence for } H = 0.00242\ , \quad \mu = 186.$$

Lord Rayleigh[1] experimenting with still feebler forces, going down even to 0.00004, found for iron wire not annealed:

$$\mu = 81 + 64\,H \quad ;$$

$$\text{hence for } H = 0.00242\ , \quad \mu = 81.$$

Furthermore, "the permeability of iron for small magnetizing forces increases with rise of temperature, slowly at first, and afterwards more rapidly, until the iron is red hot, when it suddenly falls to 1, and the iron becomes non-magnetic. In an experiment by Hopkinson with a magnetizing force of 0.3, the permeability of an iron ring was 11,000 at a temperature of 770°, and only 1.14 at a temperature of 785" (Everett's C. G. S. System of Units, 1902, p. 188). The question of the effort of pressure on the permeability would likewise have to be considered.

[1] EWING, J. A. Magnetic Induction in Iron and Other Metals. Third Edition revised, pp. 124–127.

It would seem possible, therefore, that the average magnetic permeabilty of the ferric substances in the Earth's crust might, under certain conditions, be as high as 135. But it should be remembered that, strictly speaking, it can not be assumed, as was done above, that the constants of the external field, derived from surface observations, are a true representation of the magnetic field of distant electric currents; for the magnetized Earth will itself affect the lines of magnetic force of the atmosphere's magnetic system for some distance above the surface.[1] With the aid of changes produced in the Earth's magnetic forces by disturbances, further clues may possibly be obtained from time to time to the Earth's magnetic permeability, thus determining whether or not, for example, the magnetization of our planet is at present in a saturated condition.

35. In the discussion thus far only the simplest possible case of the Earth's magnetization has been considered, viz., uniform magnetic systems whose magnetic axes are coincident with the axis of rotation; the same reasoning applies, however, to the entire Earth's field. We restricted ourselves to the simple system merely to avoid complexity in the presentation and to enable any one readily to follow the line of argument.

The chief value of the hypothesis that the Earth's magnetization is due to external magnetizing currents, consists of course at present in the many new questions it immediately raises, and the fresh incentives given to investigation. Maxwell is credited with the remark, "I never try to dissuade a man from trying an experiment; if he does not find what he wants, he may find out something else." So it may be here—if that which is sought is not found, perhaps something else of value will result.

Simple Positive Magnetic Perturbations.

36. If it is true, as shown by Table VIII of No. II, that sudden magnetic perturbations are propagated more decidedly in one direction than another, and that they differ in this respect from seismic disturbances which proceed in all directions from the center of disturbance, then a harmonic analysis of the disturbance effects should furnish further evidence. A definite electric or magnetic system must be accompanied by equally definite effects on our suspended magnetic needles. Knowing the latter, we ought in turn

[1] *Cf.* Ewing, *idem*, p. 24.

to be able to determine the general character, at least, of the producing system.

The beginning of the disturbance of May 8, 1902, may be taken as typical of the general type of perturbation considered in this section, viz., an increase in the horizontal intensity over the whole, or at least the greater part, of the Earth, and a decrease in the vertical intensity in the northern magnetic hemisphere, with an increase in the southern.

For the general method of analysis employed the reader is referred to *Terr. Mag.*, v. 15, pp. 21-30, and to No. II, § 6-8. It is found that the magnetic system which could produce the perturbations observed at the beginning of the disturbance of May 8, 1902, was a twofold one; the first, the stronger, consisted of a set of electric currents in the upper regions, circulating eastward around the Earth, if negative currents, and the reverse if positive ones; the second, a weaker system, was contained within the Earth and possessed the characteristics not of an induced electric system, but of directly induced magnetism of the same sign as that of the Earth's own field.

To show this Table X has been drawn up with the aid of the data already given in Tables I and IX.

TABLE X. *The Earth's Permanent and the Disturbance Magnetic System of May 8, 1902.*

QUANTITY	TERRESTRIAL FIELD		BEGINNING OF DISTURBANCE		QUANTITY
	Mean of 1843 and 1885		May 8, 1902		
	Internal	External	Internal	External	
$-g_{10}=M_p / R^3$	$+31902\gamma$	$+208\gamma$	$+5.28\gamma$	$+15.59\gamma$	$-g_{10}=M_p / R^3$
$-g_{11}$	$+2567$	-110	$+0.90$	$+0.18$	$-g_{11}$
$-h_{11}$	-5900	-54	-2.51	-4.82	$-h_{11}$
M_e / R^3	-6434	$+123$	-2.67	-4.82	M_e / R^3
M / R^3	$+32545$	$+242$	$+5.92$	$+16.32$	M / R^3
Φ_n	78° 36′ N	59° 30′ N	63°.3 N	72°.8 N	ϕ_n
λ_n	66 29 W	153 51 W	70.3 W	87.8 W	λ_n

37. Comparing the values of the coefficients given in the first three lines, it will be seen at once that the disturbance system of May 8, 1902, is in general similar to the permanent magnetic systems of our planet: it is, in fact, a miniature reproduction of the Earth's own magnetization. This will be better appreciated by a comparison of the figures in the last two lines which define the position of the respective magnetic north poles, and hence give the direction of the magnetic axes of the various systems. Please note that the disturbance magnetic poles, both of the Earth (internal system) and of the atmosphere (external system), lie between those of the permanent magnetization. Note again that the magnetic axis of the atmospheric (external) disturbance system is displaced to the west of that of the Earth's (internal) disturbance system, precisely as was the case with regard to the permanent magnetization. *Cf.* § 27.

If we start with the external systems and assume these to be the primary or magnetizing currents, both with regard to the permanent magnetization and its temporary derangement, then the magnetic axis of the internal system, in each instance, is found displaced to the east, hence, in the direction of rotation. This fact, as will be seen later, has an important physical bearing.

The analysis of the disturbance of January 26, 1903, as far as it could be made on the basis of the disturbance effects in the horizontal components, X, Y (Z data being insufficeint), revealed similar characteristics to those of May 8, 1902. *Cf. Terr. Mag.*, v. 15, p. 28, and Table I, No. 1.

The general effect, accordingly, of the type of disturbance here considered, was to superpose, on the Earth's existing magnetic field, a subordinate magnetic system possessing essentially the same characteristics as the permanent field, differing from it only in degree; in brief it increased momentarily the Earth's magnetization, and hence might be termed a *simple positive magnetic perturbation.*

38. The analysis made shows that these positive magnetic perturbations are to be referred primarily to an overhead system of electric currents which, if negative, would have to circulate around the Earth from west to east, in the direction of the Earth's rotation, or in the same direction as the times of beginning were found, in general, to progress for the great majority of the thirty-eight cases given in Table VIII. One line of investigation thus supports the other. Looking down on the negative currents in the

direction of the North Pole, they would be found going around anti-clockwise, thus fulfilling the laws of electro-magnetism. *Cf.* § 28.

Birkeland, on the other hand, attempts to refer the opposite type of disturbance, what he terms the "negative equatorial magnetic perturbation," to negative electric currents progressing eastwardly. We can not both be right. I have already called attention to an error which appears in the diagrams given in Birkeland's first volume; his current arrows all require to be reversed. As he has drawn them they do not follow the well-known electro-magnetic laws. Thus, for example, he has positive electric currents circulating anti-clockwise around a north-end-attracting or a south-seeking pole. See my remarks, *Terr. Mag.*, v. 15, p. 29, last paragraph, and this number § 28-30. Unfortunately Birkeland has thus far made no mathematical analysis of any of the disturbances treated by him; otherwise he himself would have discovered the untenability of some of his views.

The type of disturbances which Birkeland wishes to refer to equatorial currents is found to be merely a general disturbance of the entire magnetic condition of the Earth, of such a simple character that the first harmonic alone may suffice for a sufficiently complete representation of the observed perturbations. The theory thus far advanced in these papers is that the same electric current system which suffices for the production of the Earth's magnetization may also suffice to account for the production of the disturbances considered. All that is necessary to assume is that, due to some cause, the strata in which the permanent external currents exist are made momentarily more conducting and, in consequence, the existing currents are either intensified or weakened as the case may be; in brief the disturbances are merely the result of variations in the existing systems. While there may be abundant causes for a variation in the electrical conductivity of the aerial regions, the opportunities for cathode rays to come within range so as to affect our magnetic needles in the manner observed are comparatively few, as is fully shown by Störmer's mathematical work.

On the Magnetic Disturbances of Dec. 28-31, 1908.

39. These extremely interesting disturbances differ from the kind discussed in the previous section in several important respects. A preliminary examination would indicate that these are cases of

"negative magnetic perturbations." Their general effect was to superpose a magnetic field opposite to that of the Earth, in short, diminish momentarily the Earth's prevalent magnetization; their area of action was a comparatively restricted one. These perturbations were not felt over the whole Earth within a few minutes of the same absolute time, as was the case with the disturbances previously considered; instead the intervals between the recurrences in different parts of the globe were to be measured by hours and even a day.

Attention was first called to these peculiar magnetic disturbances by D. L. Hazard, of the United States Coast and Geodetic Survey, *Terr. Mag.* v. 14, p. 37, and recently R. L. Faris, of the same organization, has collected information regarding them from a large number of observatories over the globe, *Terr. Mag.* v. 16, pp. 13-24. From Table XI, drawn up with the aid of Mr. Faris's data, it will be seen that these disturbances did not extend much over one-half hour; they occurred on a practically undisturbed day. The maximum deflection in the horizontal component of the Earth's magnetic intensity amounted to about one five-hundredth part.

Four times out of eight cases the region over which the disturbance prevailed was the American continent and the Pacific

TABLE XI.—*Time of Occurrence and Region Covered by Disturbances of December 28-31, 1908.*

Case	Greenwich mean civil time	Approximate region embraced by disturbance		Average duration	Interval between successive disturbances
		From — Local mean time	To — Local mean time		
	d h m	d h m	d h m	m	h m
A	28 17 16	Porto Rico..28 12 54	Honolulu ...28 6 44	28	
					24 21
I	29 17 37	Porto Rico..29 13 15	Honolulu ...29 7 5	31	
					8 39
II	30 2 16	Honolulu ...29 15 44	Mauritius ...30 6 4	39	
					8 18
III	30 10 34	Alibág 30 15 25	Porto Rico..30 6 12	40	
					3 24
B	30 13 58	Falmouth ...30 13 38	Baldwin 30 7 37	26	
					3 53
C	30 17 51	Porto Rico..30 13 29	Honolulu ...30 7 19	30	
					1 5
D	30 18 56	Porto Rico..30 14 34	Honolulu ...30 8 24	40	
					8 48
IV	31 3 44	Honolulu ...30 17 12	Mauritius ...31 7 34	40	

Ocean as far as Honolulu; in one case the region was limited to the Atlantic Ocean and the American continent; twice it was in eastern Asia, and but once in Europe. Hence, had we been obliged to rely solely upon the magnetic records from the region of the Earth, Europe, where the majority of magnetic observatories exist (about twenty), we would have had to report but one magnetic disturbance between December 28 and 31, 1908, instead of actually eight. This fact illustrates convincingly the folly of increasing greatly the number of magnetic institutions in the same region of the globe.

40. Now why is it that these particular magnetic perturbations were confined each time to but a portion of the globe? Table XI shows that the intervals in time between the successive occurrences range from $1^h\ 5^m$ to $24^h\ 21^m$, whereas the apparent velocities over the area covered at any particular appearance of the disturbance is on the order of the quantities previously found for the first type of disturbance discussed. The question immediately arises, therefore, as to whether we are dealing here with *two* velocities. Have we, for example, a vortex consisting of very rapidly moving electrical charges, an Earth-spot, as it were, the vortex as a whole, however, moving comparatively slowly over the Earth? Or are we to suppose that at each recurrence the disturbance was formed anew? No matter what view we adopt, it is evident that we are about to find out another important fact regarding disturbances.

Determining the local mean time (Table XI) of the extreme stations at which the disturbance was recorded whenever it occurred, it is immediately seen that *only the observatories in the daylight zone were affected.* Wherever the local time was somewhere between 4 P. M. and 6 A. M., no effect was obtained. Hence, the conclusion is inevitable that *solar radiations of some kind must have played an important part in the production of these disturbances.* There were at the time on the Sun's visible disk some peculiarly eruptive spots which may have to be held responsible for these magnetic disturbances.

A mathematical analysis of this type of magnetic perturbation is at present under way, but it has already become sufficiently evident that we are dealing with a much more complex system than in our first type.

The possibility of a purely regional disturbance was predicted in vol. 15, p. 25, viz.:

I confidently expect, as soon as a complete analysis has been made of magnetic disturbances covering the greater portion of the Earth, it will be found, that the disturbance field, in general, presents all the characteristics of the terrestrial, primary one, the disturbances will themselves reveal effects from terrestrial, continental, regional, and even local causes (Earth currents, for example, whose path and intensity depend upon local character of soil, etc.).

This statement was based on the following law already announced (vol. 15, p. 22) which will receive further exemplification in a future number, *viz.*:

Alterations in the Earth's magnetic condition, whatever their nature or origin may be, appear to be distributed over the globe according to a law profoundly dependent upon that governing the distribution of the Earth's own primary magnetic forces.

According to this law, a magnetic disturbance originating somewhere on the Earth would not, necessarily, like a seismic disturbance, spread out equally in all directions. Chree in his discussion of the magnetic disturbance of May 8, 1902, assumed the simple, seismic law to hold.[1]

ADDENDUM.

41. As the Journal is about to go to press the issue of *Nature* of Feb. 2 is received, from which it is noticed on p. 461 that Professor Schuster presented a paper before the Royal Society on Jan. 26th entitled "The origin of magnetic storms" in which a critical examination is made of the theory that magnetic storms are caused by streams of electrified corpuscles ejected from the Sun. Schuster, after various calculations, reaches the following conclusions:

If magnetic disturbances are produced by rays emanating from the Sun, it can therefore only be in an indirect manner. We may imagine that the injection of corpuscles ionizes the upper portion of the Earth's atmosphere, and consequently renders the already existing electromotive forces more effective, or we may imagine that the approach towards the Earth's magnetic field of highly conducting material containing ions of both kinds acts by induction. The effect of such induction would primarily be an increase in the horizontal and a diminution of the vertical forces, while the currents induced in the Earth, tending to diminish the horizontal forces, would, owing to their inertia, die out more slowly, so that a semi-permanent effect would be left after the storm.

It will be seen that the theory as set forth thus far in Nos. I and III is entirely in harmony with Schuster's conclusions; it is in fact largely based on his previous researches. He and I are in agreement that the real origin of our magnetic disturbances is to be referred primarily to an outside electric system situated somewhere in our own atmospheric regions.

[1] National Antarctic Expedition, 1901–04. Magnetic Observations, p. 180. London, 1909.

MAGNETIC STORMS RECORDED AT THE CHELTENHAM MAGNETIC OBSERVATORY.

OCTOBER 1 TO DECEMBER 31, 1910.

Latitude: 38° 44′.0 N; longitude: 76° 50′.5 or 5h 07m.4 West of Greenwich

GREENWICH MEAN TIME				RANGE		
Beginning		Ending		D (Declination)	H (Hor'l Int.)	Z (Ver'l Int.
	h m		h	′	γ	γ
Oct. 1	23 09	Oct. 4	23	26.2	102	70
Oct. 5	18 21	Oct. 7	3	24.0	133	118
Oct. 12	2 27	Oct. 14	9	32.7	111	72
Oct. 19	4 11	Oct. 22	10	24.2	120	96
Oct. 25	0 35	Oct. 28	9	45.0	113	57
Nov. 16	4 02	Nov. 19	18	28.1	126	50
Nov. 29	7 32	Dec. 1	9	20.4	92	53
Dec. 13	3 35	Dec. 14	11	23.4	83	22
Dec. 15	1 05	Dec. 16	12	24.3	100	35
Dec. 28	5 32	Dec. 30	11	20.8	125	48

O. H. TITTMANN, *Superintendent, Coast and Geodetic Survey.*

J. E. BURBANK, *Observer-in-Charge.*

NOTES

1. We regret to be obliged to record the deaths during the past year of the following investigators who have made valuable contributions to terrestrial magnetism or to atmospheric electricity:

Manuel Moreno y Anda (Mexico City, Sept. 26, 1910). *Knut Johan Ångström* (Upsala, Mar. 4, 1910 at age of 53 years). *Bernard Brunhes* (director of the Puy de Dôme Observatory 1901–'10, member of the Commission on Terrestrial Magnetism of the International Meteorological Committee, died at Clermont-Ferrand, May 10, 1910). *Felipe Valle* (director of the Tacubaya Observatory 1897–1910, died Sept. 1, 1910).

2. *Prof. J. C. Beattie* was presented with the South African medal for his magnetic and other work by Dr. T. Muir, president of the South African Association for the Advancement of Science, at the opening meeting of the Association at Cape Town on October 31, 1910. *Dr. V. Conrad* has been appointed "ausserordentliche Professor für kosmische Physik" at the University Czernowitz. *Professor Dr. Adolf Schmidt* was recently elected a member of "Die Leopoldinisch-Carolinische deutsche Akademie der Naturforscher in Halle." *L. A. Bauer* was awarded by the Belgian Royal Academy of Sciences, Letters and Arts, Dec. 1910, the Charles Lagrange Prize of 1200 francs, period 1905–08, for his various researches in terrestrial magnetism.

ATMOSPHERIC ELECTRICITY OBSERVATIONS TAKEN ON THE "BELGICA" IN 1907 DURING THE DUKE OF ORLEANS' ARCTIC CRUISE.[1]

In 1907 the "Belgica" made a trip into the Kara Sea, and for the first time atmospheric electricity observations were made in high latitudes on board ship. Lieutenant Rachlew undertook and made observations in the dispersion (Zerstreuung) of electric charges in free air, and of the radioactivity of the atmosphere and snow. The Elster and Geitel apparatus was used, being mounted on a suitable stand amidships, and great care was taken to eliminate the flapping movements of the electroscope leaves due to the motion of the ship. The insulations were carefully watched and, despite the humidity of the air, were kept in good state.

Twenty-six observations were performed as to the dispersion of electric charges of both signs and the loss per minute tabulated as a percentage of the initial charge. The average results of these percentages for the cruise were as follows: for the positive charge, a+, 0.98%, and for the negative charge, a—, 1.32%. The proportionality, q, of a— to a+, was 1.35. Astonishingly large results of q, as high as 11, were obtained on several days, and on such days heavy off-shore winds were blowing. In general it was shown that the loss of electrical charges was much less on sea than on land.

The radioactivity of the atmosphere was detected by the method of Elster and Geitel, in which the active deposit was collected on a suspended copper wire to a high negative potential. Here the Zamboni pile was useless as the humidity had destroyed its insulation. However, the difficulty was splendidly overcome by the use of an induction coil and Leyden jar. In general traces of radioactivity were found, but, as in the case of the previous observations, the radioactivity was much higher on days when there was a heavy land breeze. Finally, in an attempt to determine the nature of the deposit, a curve showing the rate of decay of activity of the deposit was drawn from experimental observations, and by a comparison with the curve of Curie and Danne, it was found to be due entirely to radium emanation, no trace of thorium being found.

Unfortunately, owing to an accident to the ship, they were forced to return without wintering in Arctic regions, as had been originally intended. However, the results obtained are of high scientific importance.

H. F. JOHNSTON.

Department of Terrestrial Magnetism,
Carnegie Institution of Washington.

[1] Bulletin de la Société Belge D'Astronomie, October, 1910; communicated by G. Südeling (Berlin).

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A. Terrestrial Magnetism.

ADMIRALTY, BRITISH. Results of magnetic observations for year 1909. Received from His Majesty's ships and Royal Indian Marine. London, 1910, H. D. 226 (14), 33½ cm.

AMBRONN, R. Beobachtungen der magnetischen Deklination zu Göttingen in der Nacht vom 18. auf den 19. Mai 1910. Meteor. Zs., Braunschweig, v. 27, No. 7, July 1910 (318-319).

ANDRÉ, CH. The passage of the Earth through the tail of Halley's comet. Observations with both the electrometer and magnetometer gave negative results. (Read before Paris Acad. Sci., May 25, 1910.)

ANGOT, ALFRED. The magnetic and electric variations on the nights of May 18 and 19, 1910. None of the variations noted can be regarded as exceptional. (Read before Paris Acad. Sci., May 25, 1910.) Nature, London, v. 83, No. 2118, June 2, 1910 (419).

ANGOT, ALFRED. The secular variation of the magnetic elements in the region of Paris. (Read before Paris Acad. Sci., Feb. 28, 1910.)

ANGUIANO, ANGEL. Anales de la Comision Geodesica Mexicana. (Tacubaya, D. F.) [Contains Moreno y Anda Manuel: Observaciones magneticas y meteorologicas en Zacatlan (Pueblo) (107-136).] Mexico, 1908, v. II, (458), 36 cm.

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Terrestrial Magnetism

and

Atmospheric Electricity

VOLUME XVI JUNE, 1911 NUMBER 2

COMPARISONS OF MAGNETIC OBSERVATORY STANDARDS BY THE CARNEGIE INSTITUTION OF WASHINGTON.[1] No. I.

By J. A. Fleming.

The project of a general magnetic survey of the globe, undertaken by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, and co-operating organizations, makes necessary the determination of possible instrumental differences existing between the standards used in different countries. The pioneer work of van Rijckevorsel, Solander, Rücker and Thorpe, Moureaux, Palazzo, Bauer, and others, called attention to the need of such instrumental comparisons, and so various resolutions on this subject were passed by the Magnetic Commission of the International Meteorological Committee, which have recently been put into effect by various countries. The present contribution records the results obtained by the Carnegie Institution of Washington in the course of its magnetic operations, and under the direction of Dr. Bauer. The accuracy here striven for is that which, in general, will be amply sufficient for ordinary magnetic survey purposes. For this reason the Department makes use of its usual field instruments and methods; the results indicate that all needful accuracy has been secured. We must record here our indebtedness to the various observatory directors for the very cordial assistance rendered, as well as to express to them our appreciation for the uniform courtesies extended to the respective observers of the Department.

[1] *Cf.* Bauer, L. A., and Fleming, J. A. Chief results of the intercomparison of magnetic instruments obtained by the Carnegie Institution of Washington (Abstract). Bericht über die Versammlungen des Internationalen Meteorologischen Komitees und dessen Kommission für Erdmagnetismus und Luftelektricität. Berlin, 1910, pp. 89–91. Also Fleming, J. A., and Pearson, J. C. Carnegie Institution comparisons of magnetic standards during 1908. *Terr. Mag.*, v. 14, 1909, pp. 3–16.

Instruments.

The *magnetometers* used have been of two patterns, although the details are in many particulars very similar. In the first years of the Department's work, use was made, by courtesy of the Superintendent of the United States Coast and Geodetic Survey, of that Bureau's standard magnetometers.[2] These were made in the instrument shop of the Survey, many of the details and features being such as had been indicated as desirable in the field operations by various observers. They are of the magnetometer-theodolite type, that is to say, one base and horizontal circle serves for the mounting of the magnetometer and theodolite attachments; the resulting compactness makes them very portable without any great sacrifice in accuracy of result. The deflection bars are of brass, each in two pieces. The magnets are hollow bars, the exterior surfaces being octagonal prisms, the interior surfaces are cylindrical; the divided scales and collimating magnet lenses and mountings are screwed on the ends by screw threads cut in the magnets, while for centering in the stirrups there are shallow grooves at the middle of the magnets. The suspension is of silk fiber; for the purpose of taking out torsion a brass bar equal in weight to the long magnet is used. So far as possible the magnet-houses are made of wood in order to eliminate possible effects of impure brass, as also damping in oscillation work. The details of the instruments are given in Table I. This type of instrument is shown in Figure 1.

Soon after the inauguration of the work of the Department magnetometers combining the best features of the Coast and Geodetic Survey pattern and that of the Magnetic Survey of India[3] were designed. These are also of the theodolite-magnetometer type and are portable, although, because of increased detail and accuracy, somewhat heavier and larger than the Coast and Geodetic Survey pattern, but intermediate between it and the Survey of India magnetometer. In order to eliminate questions arising because of irregularities in shape of magnets these were made as perfect hollow cylinders of such dimensions as to make theoretically the second distribution coefficient zero; the magnets are enclosed in aluminum sheaths in which the optical and centering arrangements are carried. The divided scale for declination work is not put in the focus of the collimating lens of the magnet, but as a scale diaphragm in the mag-

[2] BAUER, L. A. The Coast and Geodetic Survey magnetometer. *Terr. Mag.*, v. 5, 1901, pp. 30–31.

[3] FRASER, H. A. D. The unifilar magnetometer of the Magnetic Survey of India. *Terr. Mag.*, v. 6, 1901, pp. 65–69.

netometer telescope. The suspension used is a phosphor bronze ribbon; the torsion is readily removed by a torsion plummet with graduated rim, read by a secondary lens which may be turned into the optical system of the magnetometer telescope. The details of these instruments are given in Table I. In connection with details given it should be noted that magnetometers 2 to 4 were made some time before 5, 7, 8, and 10, and that as a result some of the purely mechanical details and dimensions were slightly altered. Figure 2 shows this type of instrument.

Magnetometer 36, the property of the Coast and Geodetic Survey, was also used in the early work. It is substantially the Magnetic Survey of India pattern, but without the vertical circle and with the dimensions of the magnets so modified that theoretically the second distribution coefficient will be zero. With this instrument it was necessary to carry an additional theodolite for the astronomical work.

Magnetometer 15, the property of the Meteorological Service of Canada, made for that Bureau in the shop of the Department, is of the latest portable design. A detailed description is given in the previous issue of this Journal.[4]

Magnetometer 2025, the property of the Samoan Observatory and made by Tesdorpf, was used by the Department during 1906. A complete description is given by Prof. K. Haussmann in the January number of the Zeitschrift für Instrumentenkunde for 1906.

The *dip circles* used are all by Dover, with the exception of No. 18, which is by Casella. Numbers 171, 172, 177, 178, 201, belonging to the Department, and 18 of the Coast and Geodetic Survey, are of the usual land instrument form; the vertical circles may be read by verniers to one minute. This form is illustrated in Figure 3. Circles 169, 189, and 35 (Dover No. 168), the first two belonging to the Department and the last to the Coast and Geodetic Survey, are of the Lloyd-Creak pattern for use at sea; their vertical circles are graduated into ten minute spaces and the nearest minute estimated (this is readily done, as the face of needle and graduation of vertical circle are in same plane). The Lloyd-Creak pattern of dip circle is shown in Figure 4. All of the dip circles are arranged for the observation of relative total intensity by Lloyd's method[5] and for

[4] FLEMING, J. A. Two new types of magnetometers made by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. *Terr. Mag.*, v. 16, 1911, pp. 1–12.

[5] BAUER, L. A. Results of magnetic observations made by the Coast and Geodetic Survey between July 1, 1903, and June 30, 1904. *App.* 3, *Report* 1904, *U. S. Coast and Geodetic Survey, Washington, D. C.*, 1904, pp. 196–198.

Table I. Details and Constants of Magnetometers Used in the Intercomparison Work by the Carnegie Institution of Washington

Detail and Constant	Magnetometer No.												
	2	3	4	5	8	7	10	15	36	1	17	19	20
Property of	C. I. W.	C. I. W.	C. I. W.	C. I. W.	C. I. W.	C. I. W.	C. I. W.	(c)	U. S. C. & G. S.	C. I. W.	U. S. C. & G. S.	U. S. C. & G. S.	U. S. C. & G. S.
Long magnet:													
Style	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(a)	(a)	(a)	(a)
Inside diameter in cm.	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.56	0.76	0.7	about as for 1	about as for 1	about as for 1
Outside diameter in cm.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.79	1.02	1.2			
Length in cm.	7.50	7.50	7.50	7.50	7.50	7.50	7.50	5.60	9.27	7.2			
Short magnet:													
Style	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(a)	(a)	(a)	(a)
Inside diameter in cm.	0.61	0.61	0.61	0.61	0.61	0.61	0 61	0.45	0.62	0.7	about as for 1	about as for 1	about as for 1
Outside diameter in cm.	0.82	0.82	0 82	0.82	0.82	0.82	0.82	0.65	0.83	1.2			
Length in cm.	3.50	3.50	3.50	3.50	3.50	3.50	3.50	2.60	4.33	6.0			
Horizontal circle:													
Diameter in cm.	12.5	12.5	12.5	12.5	12.5	12.5	12.5	10.1		11.0	11.2	11.2	11.2
Least count vernier	20″	20″	20″	20″	20″	20″	20″	1′	20″	1′	1′	1′	1′
Kind of suspension	phosphor bronze	phosphor bronze	phosphor bronze	phosphor bronze	phosphor bronze	phosphor bronze	phosphor bronze	phosphor bronze	phosphor bronze	silk	silk	silk	silk
Scale value for declination work	1′.50	1′.49	1′.49	1′.48	1′.48	1′.49	1′.50	2′.00	1′.38	2′.28	2′.00	2′.00	2′.00
Moments:													
Inertia, long magnet, stirrup, etc., in C. G. S. units	162	166	156	234	237	239	238	66	248	208	187	188	179
Magnetic, in C. G. S. units	620	673	630	660	528	642	620	285	807	174	417	359	398
Deflection distances used, in cm.	25; 27.5 30; 40	25; 30 40	25; 30 40	25; 27.5; 30 35; 40	25; 30; 40	25; 27.5; 30 35; 40	25; 30 40	20; 25; 28	30; 40	30; 40	30; 40	30; 40	30; 40
Distribution coefficients:													
P	+15.78	+10.71	+14.87	+14.59 (e)	+14.67	+16.51	+13.25	+7 29	+18.94	−1.90	−1.24	−0 40	−0.96
Q	−1000	+1000	−881	− 640 (e)	+ 24	−1277	+490	+ 84	+511	(d)	(d)	(d)	(d)
Induction coefficient, k	0.0116	0.0088	0.0116	0.0063	0.0063	0.0063	0.0063	0.0104	0.0092	0.0516	0.0120	0.0130	0.0166
Temperature coefficient, q	0.00035	0.00041	0.00035	0.00046	0.00037	0.00048	0.00035	0.00045	0.00041	0.00066	0.00047	0.00030	0.00048

(a) These magnets are hollow steel bars with cross sections of octagonal periphery on the outside and circular on the inside.

(b) These magnets are hollow cylinders.

(c) Meteorological Service of Canada.

(d) The values given under the heading P are values of P' assuming that $(1 + Pr^{-2}) = (1 + Pr^{-2} + Qr^{-4})$.

(e) Values used after the accident of March 28, 1910, are $P = +15.56$ and $Q = -570$.

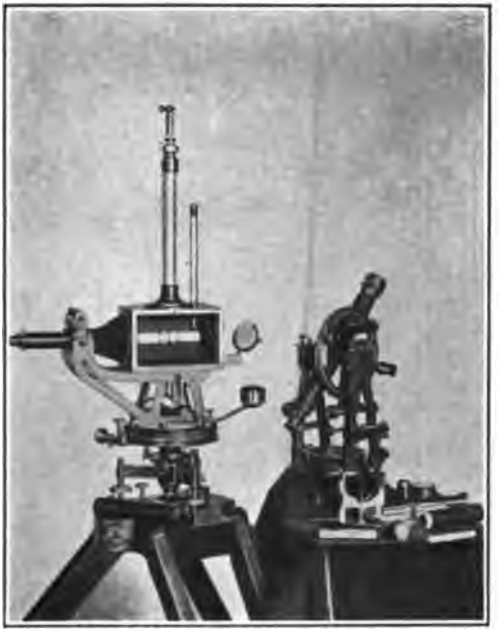


FIGURE 1.

FIGURE 2.

FIGURE 3.

FIGURE 4.

TYPES OF INSTRUMENTS.

the determination of approximate declinations by compass attachments. In no case, however, have the data by these methods been used in the intercomparison results.

Methods of Observations.

Observations were made for the elements after the usual scheme at land stations, no elaboration except in number being attempted. A declination value results from the mean of two scale readings, magnet erect, four, magnet inverted, and two, magnet erect and the necessary mark and magnet circle readings. Single values of horizontal intensity depend upon two sets of oscillations of ten differences of time for seventy or more oscillations in connection with two sets of deflections at two distances and four positions of deflecting magnet for each distance in the order to eliminate diurnal variation in declination. Single values of dip depend on the observation of both polarities in the four positions of needle and horizontal circle for each polarity of one or more needles as may be indicated in the tabulations. Horizontal intensity is obtained by the formula: $mH = \frac{\pi^2 K}{T^2}$ and $\frac{H}{m} = \frac{C}{\sin u}$, where T is the time of one oscillation corrected for rate of chronometer, torsion, temperature effects, amplitude, and induction; K is the moment of inertia of the oscillating magnet and m its magnetic moment; u is the mean deflection angle, and C is the quantity corrected for changes in length of brass deflection bar with temperature, involving the deflection distance r, induction μ, and distribution coefficients P and Q, thus $C = \frac{2\left(1 + \frac{P}{r^2} + \frac{Q}{r^4}\right)}{r^3\left(1 + \frac{2\mu}{r^3}\right)}$. It should also be stated that the attempt is always made to eliminate instrumental errors as far as possible by different orientations of the movable parts on the various days (*e. g.*, different orientation of footscrews, readings on different parts of circle, etc.).

Standards of the Carnegie Institution of Washington.

The provisional standards used by the Department are: in declination, Department magnetometer 3; in dip, Department Schulze earth inductor 48 with a correction of —0.′5 to observed values; in horizontal intensity, Department magnetometer 3 with a correction of $+0.00015H$[6] to observed values so as to conform with the pre-

[6] In the abstract of the intercomparisons which appeared in the "Bericht über die Versammlungen des Internationalen Meteorologischen Komitees und dessen Kommission für Erdmagnetismus und Luftelektrizität (Berlin, 1910, pp. 89-91)," this correction is erroneously given as —0.0030 H, the difference having arisen from using in the preliminary work a value of the moment of inertia of the long magnet and suspension since shown to have been incorrect due to a defective (probably non-homogeneous) inertia bar.

liminary 1907 "International Magnetic Standard,"[7] which was based on a discussion of numerous comparison data from various sources.

Corrections of Instruments.

The corrections of each instrument on these provisional standards are determined with great care before and after use in the field. Further checks are provided by field intercomparisons among observers of the Department, whenever opportunity permits. The comparisons at Washington are made practically under the same conditions as prevail in the field, and as the result of an extended experience involve *simultaneous* observations with both the standard instrument and the one being compared, as well as the *interchange* of *instruments* and observers between the stations in order that there may be no uncertainty arising from ignorance of precise station differences, if any, due to local attraction, either natural or an unsuspected artificial one. *The interchange of station for instruments and simultaneity of observation are very important matters;* unfortunately they have been often disregarded in intercomparisons, and as a result, unusual differences have often been attributed to inaccuracies of observation, unknown torsion effects, insufficient accuracy of instrumental detail, changes in constants and distribution coefficients, and the like. That all such uncertainties and the accompanying loss of time in lengthy discussion may be avoided even when there are local disturbances of considerable amount has been amply proved in the work of the Department. Thus, for example, at the Bronx Park Station, New York City, a local disturbance (probably artificial in character) of over one degree in declination for the same height of magnet, and of a second difference of nearly one minute for differences of one centimeter in the height of magnet, were *effectively controlled* and the results made use of in deducing corrections; at Washington there is a natural local disturbance in horizontal intensity of 39 gammas between the stations used for standardization purposes. Unless it is known *absolutely* from numerous previous determinations that the magnetic elements are the same over a region covered by two stations, simultaneous work with interchange of instruments from one station to the other is absolutely essential.

The following specimens of the intercomparison work in declination and horizontal intensity carried out with magnetometer No. 5 at Washington and at the field station, Rumeli Hissar, near Constantinople, Turkey, serve to show the scheme used to determine corrections on "standard" instrument. P. E. stands for the computed "probable error."

[7] BAUER, L. A. Preliminary note on an "International Magnetic Standard." *Terr. Mag.*, v. 12, 1907, pp. 161–165.

Results of Declination Comparisons at Washington.

(C. I. W. magnetometers 5 and 3.)

Date	Local mean time From	Local mean time To	Declination observed* C. I. W.	Declination observed* C. I. W. 5	C. I. W.—C. I. W. 5	Remarks
1907	h m	h m	° ′	°	′	
Dec. 20	14 18	14 27	−4 44.9	−4 44.6	−0.3	3 at C_m; 5 at A_m
	14 40	14 49	44.0	43.4	−0.6	
	15 22	15 31	42.9	42.7	−0.2	
	15 38	15 47	41.9	42.5	+0.6	
	16 07	16 16	41.6	42.0	+0.4	
21	13 58	14 07	44.1	44.0	−0.1	
24	10 08	10 17	40.9	41.0	+0.1	3 at A_m; 5 at C_m
	10 25	10 34	41.4	41.5	+0.1	
	10 51	11 00	41.5	42.2	+0.7	
	11 05	11 14	42.3	42.3	0.0	
	11 35	11 44	44.1	44.3	+0.2	
1908						
Feb. 12	10 04	10 13	−4 38.5	−4 38.6	+0.1	3 at A_m; 5 at C_m
	12 15	12 24	42.7	43.0	+0.3	
	13 18	13 27	44.0	44.0	0.0	
	15 20	15 29	43.6	44.0	+0.4	
Feb. 14	10 15	10 24	38.9	38.5	−0.4	3 at C_m; 5 at A_m
	12 27	12 36	42.6	43.0	+0.4	
	13 31	13 40	44.7	45.0	+0.3	
	15 33	15 42	44.5	44.9	+0.4	

Mean value (C. I. W.—C. I W. 5) = +0′.1; P. E. = ±0′.05.

* All values corrected to Station A_m; values by 3 are C. I. W. standard, values by 5 are as observed.

Results of Horizontal Intensity Comparisons at Washington.

(C. I. W. magnetometers 5 and 3.)

Date	Local mean time From	Local mean time To	Horizontal intensity obtained* C. I. W.	Horizontal intensity obtained* C. I. W. 5	C. I. W.—C. I. W. 5	Remarks
1908	h m	h m	γ	γ	γ	
Feb. 12	10 23	11 21	19932	19948	−16	3 at A_m; 5 at C_m
	11 27	12 12	921	939	−18	Values are each
	13 33	14 20	925	942	−17	from deflections at
	14 26	15 06	938	954	−16	25, 30 and 40 cm.
Feb. 14	10 23	11 26	19913	19941	−28	3 at C_m; 5 at A_m
	11 29	12 15	911	928	−17	
	13 39	14 29	916	930	−14	
	14 40	15 22	929	937	− 8	

Mean value (C. I. W.—C. I. W. 5) = −16.8γ; P. E. = ±1.3γ.
or −0.00084H; P. E. = ±0.00007H.

* All values corrected to station A_m ($C_m - A_m = -39\gamma$); values by 5 are as observed.

Results of Declination Comparisons at Rumeli Hissar.

(C. I. W. magnetometers 5 and 7.)

Date	Local mean time		Declination observed*		C.I.W.5—C.I.W.7	Remarks
	From	To	C. I. W. 5	C. I. W. 7		
1910	h m	h m	° ′	° ′	′	
Jan. 18	14 26	14 35	—2 11.4	—2 10.5	—0.9	5 at B; 7 at A
	16 18	16 27	10.0	10.7	+0.7	
19	13 07	13 16	10.4	12.0(?)	(?)	New fiber in No. 7; high winds interfering with work; value rejected in mean
21	9 48	9 57	07.9	07.7	—0.2	
	11 38	11 47	10.5	11.0	+0.5	
	12 08	12 17	11.1	11.5	+0.4	
	14 16	14 25	10.9	11.2	+0.3	
	14 40	14 49	11.7	11.4	—0.3	
	16 33	16 42	09.8	09.4	—0.4	
Jan. 26	9 53	10 02	—2 09.5	—2 09.4	—0.1	5 at A; 7 at B
	11 39	11 48	13.0	12.8	—0.2	
	12 03	12 12	11.1	11.0	—0.1	
	14 03	14 12	13.0	12.8	—0.2	
	14 23	14 32	12.2	12.8	+0.6	
	16 03	16 12	10.5	10.2	—0.3	

Mean value (C. I. W. 5 — C. I. W. 7) = 0′.0; P. E. = ±0.08.
Since C. I. W. = C. I. W. 7 + 0′.1 we have C. I. W. = C. I. W. 5 + 0′.1.

* All values reduced to station A (A — B = — 0′.6), but not reduced to C. I. W. standard.

Results of Horizontal Intensity Comparisons at Rumeli Hissar.

(C. I. W. magnetometers 5 and 7.)

Date	Local mean time		Horizontal intensity observed*		C.I.W.5—C.I.W.7	Remarks
	From	To	C. I. W. 5	C. I. W. 7		
1910	h m	h m	γ	γ	γ	
Jan. 18	14 41	16 13	25012	24993	+19	5 at B; 7 at A
19	13 20	15 10	4974	4992	—18	
21	10 02	11 31	4977	4974	+ 3	
	12 21	14 10	4989	4992	— 3	
	14 53	16 27	5011	5006	+ 5	
Jan. 26	10 05	11 35	24981	24975	+ 6	5 at A; 7 at B
	12 14	13 59	4966	4972	— 6	
	14 36	15 57	4974	4969	+ 5	

Mean value (C. I. W. 5 — C. I. W. 7) = +1.4γ; P. E. = ± 2.6γ.
or +0.00006H; P. E. = ±0.00010H.
Since C. I. W. = C. I. W. 7 — 0.00096H we have C. I. W. = C. I. W. 5 — 0.00102H.

* All values reduced to station A (A — B = — 33γ), but not reduced to C. I. W. standard.

Instrumental Corrections.

The *magnetometer corrections* given below depend usually upon two or more sets of at least twelve declination observations, and six horizontal intensity observations at three distances each, made substantially simultaneously with interchange of station as above with the standard instruments. This was not always the case in the earlier work of the Department, but in the few cases of that kind the corrections depend upon numerous observations compared with standard values at the *same* station preceding and following. The probable errors of the corrections here given are almost all of the order $\pm 0.'1$ in declination and $\pm 0.00005H$ in horizontal intensity.

Magnetometer Corrections to Provisional International Standards of Carnegie Institution of Washington.

Magnetometer	Declination	Horizontal Intensity	Remarks
1	0′.0	$-0.0006H$	After February 7, 1907
2	+0.2	$-0.00036H$	
4	+0.7	$+0.00024H$	
5	+0.1	$-0.00090H$	Before accident March 28, 1910
5	−0.1	$-0.00021H$	After March 28, 1910
7	+0.1	$-0.00096H$	
8	+0.8	$+0.00006H$	
10	+0.7	$+0.00052H$	
15	+0.1	$+0.00035H$	
17	−0.1	$+0.0012H$	
19	+1.5	$-0.0010H$	Through 1905
20	+0.5	$+0.0011H$	
36	−0.5	$+0.00113H$	Through 1906
2025	−0.5	$0.0000H$	Deflections only

The corrections are to be applied to observed values algebraically; east declinations are reckoned as positive and west declinations as negative, horizontal intensity as always positive.

After its return from the field, March 28, 1910, and just prior to intercomparison observations with the standard, magnetometer 5, with long magnet and deflection bar in place suffered a fall which damaged it; in the repairs it was necessary to straighten the deflection bar, which operation made quite an appreciable change in the deflection distances. The new constants resulting are used subsequent to the accident; fortunately the corrections were determined also in January, 1910, by comparison at the Rumeli Hissar Station, near Constantinople, Turkey, by the comparison with magnetometer 7, which was standardized at Washington only a few months previously.

In connection with an investigation of the effect, on the correction to standard in horizontal intensity, of possible changes in the values of the distribution coefficients over relatively short periods of two years or less, a careful analysis was made of all the available observations with magnetometer 5 for the determination of P and

Q. The results from twenty-three sets of deflections at three distances each at Washington in January and February, 1908, and from a least square adjustment of the observations at eight observatory stations during February, 1908, to March, 1910 (prior to accident), there being four sets or more of deflections for each of three pairs of distances at the observatory stations, were $P = +14.59$, with a probable error of ± 0.07, and $Q = -640$, with a probable error of ± 6.3. On investigation it was found that whatever values of P and Q, within the extreme range of the values for this magnetometer, were used the resultant constants *and corrections* would yield eventually the same standard value of horizontal intensity. It also appeared that over such short periods as two to three years the values of P and Q may practically be assumed constant, and that discrepancies from mean values over such periods are very probably largely the result of unavoidable errors of observation. It is to be noted that in spite of all possible care used in making the magnets of magnetometers 2, 3, 4, 5, 7, 8, and 10 true to dimension and perfect cylinders, the distribution coefficients we found considerably different[8] from the theoretical values, viz.: $P = +12.7$, $Q = 0$, computed on the basis that the ratio of pole distance to length is 0.81.

The same care as with the magnetometers is used in securing *dip needle corrections* to standard, though here greater difficulty is experienced, due to two sources: the mechanical imperfections which, although greatly reduced in Dover's instruments, still are sufficiently great to cause much trouble, and the apparent dependence of the corrections on the values both of dip, I, and total intensity, F. The latter relation is obtainable only upon the completion of a field campaign embracing large range of dips and observatory comparisons, placing reliance for standard values, other than at the standard base station, on earth inductor data. Whether the correction to an earth inductor may be considered constant for all dips is, at present, open to question. The relation may be expressed by the formula

$$F\Delta I = x + y \cdot \sin I + z \cdot \cos I.$$

Quite an extended experimental investigation has been made by the Department to determine the formula coefficients at its base station.[9] The operation, however, requires such an expenditure of time that in view of the ease with which rust traces and pits develop on the pivots, despite the best of care, it seems best to await the completion of a campaign and then deduce the corrections by a careful consideration of needle differences at the same stations, and such earth

[8] *Cf.* CHREE, CHARLES. The law of action between magnets and its bearing on the determination of the horizontal component of the Earth's magnetic force with unifilar magnetometers. *Proc. Phys. Soc. London*, 19, 1904, pp. 113-145.

[9] *Cf.* DIKE, P. H. An experimental investigation of dip needle corrections. *Terr. Mag.*, v. 14, 1909, pp. 137-146.

inductor comparisons as have been obtained. The ultimate solution of the dip circle difficulty appears to be in the suitable adaptation of the earth inductor for field use; some experiments are being made in this direction by the Department.

In very exceptional instruments it is possible to secure corrections from a careful study by groups of the differences between values obtained by four different needles and then working forward or back to the corrections to the standard at the base station. The corrections for dip circle 177, being small and the effect due to differences in F negligible, were determined in this way from the needles differences for observatory and field station grouping and made dependent only on the standardization at Washington, viz:

Corrections to standard for dip circle 177 needles.

Dip	1	2	5	6
°	′	′	′	′
+0	—0.5	—0.3	—1.4	+0.6
+10	—0.5	—0.3	—1.2	+0.6
+20	—0.5	—0.3	—1.0	+0.5
+30	—0.7	—0.4	—0.8	+0.2
+40	—0.9	—0.4	—0.5	—0.1
+50	—1.1	—0.4	—0.2	—0.1
+60	—1.3	—0.2	—0.2	+0.2
+70	—1.2	—0.1	—0.7	—0.6

For dip circles 35, 178, 169, and 189 the first reductions of the *Galilee* observations give the following values for the coefficients in the correction equation:

Circle and needle	x	y	z
	′	′	′
35—1	+2.7	—3.6	—1.4
35—2	+9.2	—4.8	—9.4
169—1	—3.9	+1.2	+0.5
169—2	—4.6	+1.5	+6.0
178—1	—1.8	—0.3	+3.1
178—2	—1.7	+0.7	+2.3
189—5	—0.7	—2.4	+1.6
189—6	—1.1	—1.3	+2.1

Dip circle 171 has been rather unsatisfactory throughout; the corrections adopted for the various needles used from time to time, as derived from a thorough examination of needle differences before development of rust on pivots, are as follows:

Mean of needles 1 and 2 during
1905 to 1906 for values of I from —60° to —70°, +0.′5.
+60° to —60°, 0.′0.
Mean of needles 5 and 6 of circle 172
during 1906 for values of I from —60° to —70°, +1.′0.
Mean of needles 5 and 6 of circle 172
and 7 of circle 178 during 1908 to 1909, 0.′0.

(During this time the pivots of all three needles developed rust pits in one or two spots on each; the mean of observed values, however, seems to yield results within 2′ or less of standard.)

The correction for dip circle 172 for the
mean values of dip by needles 1 and 2 during 1906 was, —0.′8.

For the corrections for the various dip circles, as given above, it appears that, with the exception of the mean value for needles 5 and 6 of 172 and 7 of 178 in circle 171 during 1908 to 1909, the order of the probable errors of the mean values is from ±0.′3 to ±0.′5.

Observatory Standards Intercompared.

Intercomparisons of standards have been made at the observatories listed with particulars in Table 2.

Details of Comparisons.

The values of the computed probable errors of mean result are given for each comparison; these serve to convey some idea of the relative accuracy attained in the declination and horizontal intensity comparisons. The probable errors for the result in inclination are obtained from mean values of *all* needles used in each set, thus, if six sets of comparisons each with four needles have been made at a station, the probable error is made up by considering only the six means from four needles each. Where there are two series the mean result of each has been given a weight depending upon its probable error and the weighted mean difference taken accordingly.

The reference "See first publication" refers to the article published in this Journal, Vol. 14, pp. 3-16.

The abbreviation *C. I. W.*, as used in the tables, means the value according to the provisional standards adopted by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington.

Kew Observatory.

Since the first publication Dr. Chree has concluded the investigation of his standard magnetometer for the following previously known sources of error, but not taken account of at the time of the first comparisons: (*a*) that arising from the assumption that for distribution corrections $(1 + Pr^{-2}) = (1 + Pr^{-2} + Qr^{-4})$, *i. e.*, assuming Q negligible; (*b*) that arising from neglect to take into account the bending of the deflection bar; and (*c*) that arising from error in the accepted value of the moment of inertia. The cumulative effect from all three at the time of the first comparison was to reduce the values originally given for Kew by 6.3 gammas. As is seen from the revised results for 1908 and the second series of 1910, the provisional "International Magnetic Standard" adopted by the Department is well taken as the difference on Kew is sub-

TABLE II. *Particulars of Magnetic Observatory Intercomparisons by the Carnegie Institution of Washington.*

No.	Observatory	Latitude	Longitude from Greenwich	Date	Approximate			Instruments of C. I. W.		Observer	Remarks
					D	*I*	*H*	Magr.	Dip circle		
		° ′	° ′		°	°	C G S				
1	Sitka, ...	57 03 N	135 20 W	July 22–Aug. 8, 1907, ...	+30.1	+74.7	0.155	1 ; 4	35 ; 169 ; 178 ; 189	"Galilee" III,	Same standard as No. 10.
2	Potsdam, . .	52 23 N	13 04 E	Feb. 21–28, 1910, ...	− 9.1	+66.3	0.188	5	177	J. C. Pearson,	
3	Kew, ...	51 28 N	0 19 W	Mar. 9–17, 1908, ...	−16.4	+67.0	0.185	5	177	J. C. Pearson,	
				Mar 8–12, 1910, ...	−16.2	+67.0	0.185	5	177	J. C. Pearson,	
4	Falmouth, . .	50 09 N	5 05 W	Oct. 22–29, 1910, ...	−17.8	+66.5	0.188	2 ; 4	201	"Carnegie" I,	
5	Pola, ...	44 52 N	13 51 E	Feb. 8–14, 1910, ...	− 8.5	+60.1	0.222	5	177	J. C. Pearson,	
6	Toronto, . . .	43 47 N	79 16 W	Sept. 6–8, 1906, ...	− 5.8	+74.6	0.163	20	172	P. H. Dike,	
				Oct. 8–10, 1906, ...	− 5.8	+74.6	0.163	20	172	P. H. Dike,	
7	Tiflis, ...	41 50 N	44 42 E	June 8–12, 1908, ...	+ 2.7	+56.4	0.254	5	177	J. C. Pearson,	Observatory at Karsani.
				June 28–July 3, 1909, ...	+ 2.8	+56.5	0.254	5	177	J. C. Pearson,	
8	Tashkent, . .	41 20 N	69 18 E	Sept. 3–6, 1909, ...	+ 6.3	+58.1	0.264	5	177	J. C. Pearson,	
9	Baldwin, . . .	38 47 N	95 10 W	Dec. 29, 1905–Jan. 11, 1906, . .	+ 8.5	+68.7	0.218	36	169 ; 171	J. P. Ault,	Same standard as No. 10.
				Nov. 14–22, 1906, ...	+ 8.5	+68.7	0.218	. .	178	J. P. Ault & D. C. Sowers,	
10	Cheltenham, .	38 44 N	76 50 W	Feb. 4–8, 1908, ...	− 5.5	+70.5	0.199	5	177	J. C. Pearson,	
				Mar. 24–27 1908, ...	− 5.5	+70.5	0.199	7	. . . . .	H. W. Fisk,	
				Apr. 5–8, 1910, ...	− 5.7	+70.6	0.198	5	177	J. C. Pearson,	
11	Zi-ka-wei, . .	31 12 N	121 26 E	May 14–17, 1907, ...	− 2.6	+45.6	0.331	1	178	"Galilee" III,	This observatory succeeded in March, 1908 by Lu-kia-pang.
				Sept. 11–12, 1907, ...	− 2.6	. . .	0.331	2	. . . . .	C. K. Edmunds,	
12	Dehra Dun, .	30 19 N	78 03 E	Oct. 19–23, 1909, ...	+ 2.6	+43.9	0.332	10	171	D. C. Sowers,	
13	Helwan, . . .	29 52 N	31 20 E	Apr. 21–27, 1908, ...	− 3.0	+40 6	0.300	5	177	J. C. Pearson.	
14	Havana, . . .	23 08 N	82 22 W	May 19–25, 1905, ...	+ 2.9	+53.0	0.303	19	171	J. P. Ault,	
15	Hongkong, . .	22 18 N	114 10 E	Dec. 21–24, 1908, ...	+ 0.1	+30.8	0.372	10	171	D. C. Sowers,	
16	Honolulu, . .	21 19 N	158 04 W	Sept. 19–Nov. 8, 1905, ...	+ 9.4	+40.1	0.292	36	169 ; 171	"Galilee" I,	Same standard as No. 10.
				Sept. 3–13, 1907, ...	+ 9.4	+40.0	0.292	4	169 ; 178 ; 189	"Galilee" III,	
17	Vieques, . . .	18 09 N	65 26 W	Mar., Apr., May, Sept. 1905,	− 1 4	+49.7	0.290	17	18	D. C. Sowers,	Same standard as No. 10.
18	Samoa (Apia),	13 48 S	171 46 W	May 3–8, 1906, ...	+ 9.6	−29.2	0.357	36	35 ; 171 ; 178	"Galilee" II,	Standard presumably same as No. 2 (b).
				Mar. 5–7, 1907, ...	+ 9.6	−29.3	0.357	1	35 ; 169 ; 178	"Galilee" III,	
19	Sydney (c) . .	33 45 S	151 04 E	Nov. 25, 1906, ...	+ 9.5	−63 1	0.263	2025	171	G. Heimbrod,	No simultaneous observatory data.
20	Melbourne, .	37 50 S	144 58 E	Nov. 20–24, 1906.	+ 8.2	−67.6	0.232	2025	171	G. Heimbrod,	
21	Christchurch,	43 32 S	172 37 E	July 9–21, 1906, ...	+16.5	−67.8	0.226	2025	171	G. Heimbrod,	
				Dec. 30, 1907–Jan. 9, 1908, . .	+16.6	−67.9	0.226	4	169 ; 178 ; 189	"Galilee" III,	
22	Pilar, Cordoba,	31 40 S	63 53 W	Jan 28–Feb. 2, 1911, ...	+ 9.2	−5.92	0.257	2 ; 4	201 ; R. I. 2	"Carnegie" II,	

a Observatories 1, 9, 10, 16, and 17 of the United States Coast and Geodetic Survey have all the same standards, No. 10 (Cheltenham) being the main observatory ; for this reason only the results of comparisons at 10 are given.

(b) At observatory 18 during December 1905 to March 1906 and December 1906 additional comparisons were obtained by G. Heimbrod with magnetometer 2025 and dip circle 171.

c Red Hill Branch of Sydney Observatory.

stantially zero, Watson's determination[10] of the Earth's magnetic field in international units having already indicated that the Kew standard is very close to a true one. As an indication of the absolute accuracy of observation possible with the field magnetometer used, it is interesting to note also the excellent agreement in the differences deduced between the two standards in horizontal intensity as well as declination for 1908 and 1910, and this despite an extremely difficult field campaign of nearly two years through Persia, Caucasia, Turkey in Asia, and parts of Arabia, in which the instrument was subjected to the most severe conditions to be expected in field work.

A large difference will be noted in the results for the two years as regards dip standards. The results of the first comparison appear to be rather high, although quite consistent in themselves. Two sets of simultaneous observations carried out with the Kew and the Department instruments during the work of 1908 by Messrs. Baker and Pearson indicate that the mean value of (*C. I. W.-K.*) of —2.′7 may be about 0.′7 too great numerically; it seems, however, best to adopt the mean value resulting from the two series as indicated below, its order being confirmed within about one-half minute by observations from numerous new dip circles tested at Kew just prior to their use at Washington.

Results of Declination Comparisons at the Kew Observatory.

(C. I. W. magnetometer 5.)

Series	Date	Local mean time		Declination obtained		C. I. W.—K.	Remarks
		From	To	C. I. W.	Kew		
	1908	h m	h m	° ′	° ′	′	
I	March 10	12 20	12 29	—16 22.4	—16 22.7	+0.3	
		15 15	15 24	21.8	22.9	+1.1	
		15 37	15 46	21.5	22.6	+1.1	
		15 50	15 59	20.8	22.2	+1.4	
	11	9 04	9 10	17.0	18.9	+1.9	
		10 52	10 58	19.6	20.2	+0.6	
		12 36	12 43	24.4	24.3	—0.1	
		13 00	13 07	25.5	25.5	0.0	
		14 19	14 26	23.9	23.5	—0.4	
	12	14 38	14 44	21.4	21.2	—0.2	
		16 28	16 34	19.2	19.1	—0.1	
	13	9 14	9 20	14.8	16.7	+1.9	
		10 58	11 05	18.2	19.8	+1.6	
		13 08	13 14	27.7	27.1	—0.6	
		14 26	14 35	24.9	24.9	0.0	
						+0.57	P. E. = ±0′.15

[10] WATSON, WILLIAM. A determination of the Earth's magnetic field in international units, and a comparison of the results with the values given by the Kew Observatory standard instruments. *Phil. Trans. A.*, v. 198, 1902, pp. 431-462. *Cf.* CHREE, CHAS. Mr. Watson's comparisons at Kew Observatory. *Terr. Mag.*, v. 7, 1902, p. 199.

Results of Declination Comparisons at the Kew Observatory.—Continued.

(C. I. W. Magnetometer 5).

Series	Date	Local mean time		Declination obtained		C. I. W.—K.	Remarks
		From	To	C. I. W.	Kew		
	1910						
II	March 8	9 32	9 41	−16 03.2	−16 04.7	+1.5	
		11 37	11 46	08 6	09.5	+0.9	
		12 01	12 10	09.3	09.9	+0.6	
		14 23	14 32	09.3	10.2	+0.9	
		14 43	14 52	08.8	09.7	+0.9	
		16 35	16 44	06.7	07 9	+1.2	
	9	9 13	9 22	05.1	05.7	+0 6	
		11 01	11 12	09.4	09.8	+0.4	
		12 45	12 54	10.2	10.9	+0.7	
		14 12	14 21	09.6	10.5	+0.9	
		14 22	14 31	09.6	10.3	+0.7	
	11	11 14	11 23	10.2	10.7	+0.5	
		14 08	14 17	11.2	11.7	+0.5	
		14 18	14 27	10.7	11.1	+0.4	
						+0.76	P. E. = ±0′.06

Weighted mean value (C. I. W.—K.) from I and II = +0.′7; P. E. = ±0′.06

Results of Horizontal Intensity Comparisons at Kew Observatory.

(C. I. W. magnetometer 5)

Series	Date	Local mean time		Horizontal intensity obtained		C. I. W.—K.	Remarks
		From	To	C. I. W.	Kew		
	1908	h m	h m	γ	γ	γ	
I	March 10	12 36	15 12	18504	18502	+2	
	11	9 14	10 49	499	495	+4	
	11	11 03	12 29	498	498	0	
	12	14 47	16 24	506	503	+3	
	13	9 22	10 56	491	490	+1	
	17	11 30	13 02	495	497	−2	
						+1.3γ	P. E. = ±0.6γ
	1910						
II	March 8	9 50	11 33	18494	18496	−2	
		12 17	14 20	505	502	+3	
		14 56	16 31	506	503	+3	
	9	9 26	10 59	499	500	−1	
		11 22	12 43	512	513	−1	
	11	11 28	13 04	502	500	+2	
	12	11 27	12 09	512	502	+10	Half set, weight ½
						+1.4γ	P. E. = ±0.9γ

Mean value (C. I. W.—K.) from I and II = +1.3γ; P. E. = ±0.5γ.
or +0.00007H; P. E. = ±0.00003H.

Results of Inclination Comparisons at the Kew Observatory.

(C. I. W. dip circle Dover 177.)

Series	Date	Local mean time From	Local mean time To	Needle	Inclination obtained C. I. W.	Inclination obtained Kew	C. I. W.—K. 1	C. I. W.—K. 2	C. I. W.—K. 5	C. I. W.—K. 6
	1908	h m	h m		° ′	° ′	′	′	′	′
I	March 9	15 19	17 00	1	+66 58.5	+67 01.8	−3.3			
		15 34	16 50	2	59.9			−1.9		
		15 49	16 38	5	59.8				−2.0	
		16 02	16 27	6	59.8					−2.0
	11	15 03	15 51	1	58.5	01.4	−2.9			
		15 16	15 38	2	58.9			−2.5		
		15 58	17 53	5	58.1	01.9			−3.8	
		16 17	17 44	6	58.0					−3.9
	12	9 06	10 56	1	59.1	02.2	−3.1			
		9 19	10 44	2	58.9			−3.3		
		11 02	12 33	5	59.4	02.1			−2.7	
		11 11	12 24	6	59.2					−2.9
	17	9 32	10 47	1	60.7	02.3	−1.6			
		9 45	10 40	2	59.9			−2.4		
		14 52	16 07	1	59.5	01.7	−2.2			
		15 01	15 59	2	59.6			−2.1		
		15 10	15 51	5	58.7				−3.0	
		15 18	15 42	6	59.2					−2.5
					Means		−2.6	−2.4	−2.9	−2.8

Mean value (C. I. W.—K.) from I = −2′.7; P. E. = ±0′.2.

Series	Date	Local mean time From	Local mean time To	Needle	Inclination obtained C. I. W.	Inclination obtained Kew	C. I. W.—K. 1	C. I. W.—K. 2	C. I. W.—K. 5	C. I. W.—K. 6
	1910									
II	March 9	15 15	16 44	1	+66 57.6	+66 58.3	−0.7			
		15 26	16 32	2	58.9			+0.6		
		15 36	16 22	5	58.6				+0.3	
		15 46	16 12	6	57.4					−0.9
	10	9 23	10 37	1	57.1	58.3	−1.2			
		9 32	10 28	2	57.8			−0.5		
		9 41	10 19	5	58.6				+0.3	
		9 50	10 10	6	57.9					−0.4
		11 20	12 28	1	57.5	58.3	−0.8			
		11 28	12 20	2	57.7			−0.6		
		11 35	12 11	5	58.4				+0.1	
		11 43	12 03	6	57.8					−0.5
	11	9 22	10 38	1	58.1	58.8	−0.7			
		9 30	10 28	2	57.9			−0.9		
		9 39	10 19	5	58.8				0.0	
		9 48	10 11	6	57.2					−1.6
		14 58	16 24	1	56.6	58.4	−1.8			
		15 08	16 14	2	56.4			−2.0		
		15 17	16 04	5	57.2				−1.2	
		15 27	15 52	6	56.6					−1.8
	12	9 22	10 53	1	58.8	59.8	−1.0			
		9 31	10 43	2	57.7			−2.1		
		9 39	10 33	5	58.7				−1.1	
		9 56	10 19	6	58.0					−1.8
					Means		−1.0	−0.9	−0.3	−1.2

Mean value (C. I. W.—K.) from II = −0′.8; P. E. = ±0′.2.

Mean value (C. I. W.—K.) from I and II = −1′.7; P. E. = ±0′.2.

Pola Observatory.

The Department observations were all made on the main pier in the absolute room used for the Observatory instruments. Eye readings of the variation instruments were made simultaneously for declination and horizontal intensity; for inclination, observations were made with the Observatory inductor in the middle of each dip set.

Results of Declination Comparisons at the Pola Observatory.

(C. I. W. magnetometer 5.)

Date	Local mean time		Declination obtained		C. I. W.—Pola
	From	To	C. I. W.	Pola	
1910	h m	h m	° ′	° ′	′
Feb. 8	8 52	9 01	−8 30.9	−8 30.3	−0.6
	11 15	11 24	31.9	31.6	−0.3
	14 06	14 15	32.1	32.1	0.0
	15 57	16 06	31.2	31.1	−0.1
9	8 25	8 34	30.0	29.7	−0.3
	10 15	10 24	31.4	30.9	−0.5
	14 12	14 21	35.0	34.6	−0.4
	15 50	15 59	32.7	32.0	−0.7
10	8 21	8 30	31.6	30.9	−0.7
	9 59	10 07	32.3	32.1	−0.2
	10 23	10 32	32.7	32.7	0.0
	10 47	10 56	34.0	34.1	+0.1
14	8 35	8 44	30.8	30.2	−0.6
	10 18	10 27	31.6	31.8	+0.2

Mean value (C. I. W.—Pola) = −0′.3; P. E. = ±0.′05.

Results of Horizontal Intensity Comparisons at the Pola Observatory.

(C. I. W. magnetometer 5.)

Date	Local mean time		Horizontal intensity obtained		C. I. W.—Pola
	From	To	C. I. W.	Pola	
1910	h m	h m	γ	γ	γ
Feb. 8	9 42	11 06	22214	22204	+10
	14 19	15 54	225	212	+13
9	8 39	10 12	219	208	+11
	14 26	15 48	220	210	+10
10	8 33	9 57	220	208	+12
	10 34	11 45	223	206	+17
14	8 46	10 14	224	214	+10

Mean value (C. I. W.—Pola) = +11.9γ; P. E. = ±0.6γ.
or +0.00054H; P. E. = ±0.00003H.

Results of Inclination Comparisons at the Pola Observatory.

(C. I. W. dip circle Dover 177.)

Date	Local mean time From	Local mean time To	D. C. 177 needle	Inclination obtained C. I. W.	Inclination obtained Pola	C. I. W.—Pola 1	C. I. W.—Pola 2	C. I. W.—Pola 5	C. I. W.—Pola 6
1910	h m	h m		° ′	° ′	′	′	′	′
Feb. 10	15 21	16 40	1	+60 02.1	+60 04.3	—2.2			
	15 28	16 32	2	03.3			—1.0		
	15 37	16 23	5	04.9				+0.6	
	15 46	16 15	6	05.2					+0.9
11	8 37	9 51	1	04.1	04.6	—0.5			
	8 44	9 43	2	04.9			+0.3		
	8 55	9 34	5	05.2				+0.6	
	9 03	9 26	6	06.5					+1.9
	10 32	11 47	1	04.3	04.9	—0.6			
	10 39	11 40	2	04.5			—0.4		
	10 47	11 32	5	05.3				+0.4	
	10 54	11 22	6	05.0					+0.1
	14 29	15 38	1	03.3	04.7	—1.4			
	14 36	15 30	2	03.7			—1.0		
	14 43	15 22	5	06.0				+1.3	
	14 50	15 14	6	06.0					+1.3
12	8 36	9 50	1	02.2	03.4	—1.2			
	8 44	9 40	2	03.4			0.0		
	8 52	9 31	5	04.9				+1.5	
	9 00	9 22	6	04.8					+1.4
	10 26	11 39	1	03.4	04.4	—1.0			
	10 33	11 32	2	03.7			—0.7		
	10 41	11 24	5	04.0				—0.4	
	10 50	11 16	6	05.0					+0.6
	14 25	15 27	1	03.5	03.7	—0.2			
	14 31	15 20	2	03.5			—0.2		
	14 37	15 12	5	05.2				+1.5	
	14 44	15 02	6	04.6					+0.9
		Means, ...				—1.0	—0.4	+0.8	+1.0

Mean value (C. I. W.—Pola) = +0′.1 ; P. E. = ±0′.1

Toronto Observatory.

The Department work was carried out at the Agincourt Observatory. Three stations were used; in declination a station was chosen as close as possible to the declination pier (this pier could not be occupied without dismounting the observatory declination instrument); for horizontal intensity a tent station and the regular observatory intensity pier were used; for the dip work the tent station, observatory dip pier, and the observatory intensity pier were occupied. There is no evidence of any appreciable local disturbance for any of the elements. Magnetometer Elliott 48 was at the time the Observatory standard instrument for horizontal intensity, and Dover dip circle 130 with needles 1 and 2 was the standard in dip; in November, 1906, magnetometer Elliott 98 was substituted for Elliott 48; dip circle Dover 130 has also since been superseded by Dover 200 with needles 1 and 2.

During October and November, 1909, and April, September, and October, 1910, some intercomparisons were carried out by the Meteorological Service of Canada with C. I. W. magnetometer 8 and Meteorological Service magnetometer 15. Magnetometer 8, loaned by the Department for use on the Dominion Government Expedition on the *Arctic* of 1908-1909, under Captain Bernier, was compared at Agincourt soon after its return from this Expedition. Magnetometer 15 was constructed by the Department for the Meteorological Service. The results of these intercomparisons have been courteously communicated to the Department by Prof. R. F. Stupart, Director of the Meteorological Service, and the results are herewith given with his permission. Professor Stupart states that as a result of comparisons made during November, 1906, to April, 1908, it was found that the Elliott 48 requires a correction of $+10\gamma$ or $+.00062H$ to reduce values determined by it to values determined by Elliott 98. Using this difference and working from the intercomparisons by the Department in September and October, 1906, the value of the difference (*C. I. W.-Tor.*$_{98}$) would be $-0.00102H$, which is in good agreement with the value deduced from Professor Stupart's direct intercomparisons. The mean resulting value for (*C. I. W.-Tor.*$_{98}$) is, from the results obtained by both the Department and the Service, $-0.00091H$.

The mean value of (*C. I. W.-Tor.*) in declination from all the work is $-0.'5$ with a probable error of $\pm 0.'1$.

New determinations of the instrumental constants of Elliott magnetometer 98 were made during February, 1911, by the Observatory authorities. To reduce former results to those obtained by the use of the new constants requires a correction of $-0.00116H$. Since on the basis of the old constants (*C. I. W.-Tor.*$_{98}$)$=-0.00091H$, the difference on the basis of the new constants for 98 is (*C. I. W.-Tor.*$_{98}$)$=+0.00025H$.

Results of Declination Comparisons at the Toronto Observatory.

(Magnetometer U. S. C. and G. S. 20.)

Series	Date	Local mean time		Declination obtained*		C. I. W.—Tor.	Remarks
		From	To	C I. W.	Toronto		
	1906	h m	h m	° ′	° ′	′	
I	Sept. 6	10 18	10 27	−5 46.0	−5 46.6	+0.6	
		13 11	13 20	53.3	53.0	−0.3	
	7	15 25	15 34	49.5	49.0	−0.5	
		15 55	16 04	47.6	48.0	+0.4	
	8	9 53	11 02	44.2	45.0	+0.8	
		11 56	12 05	51.0	51.3	+0.3	
						+0.2	P. E. = ±0′.14

* Same station throughout.

Results of Declination Comparisons at the Toronto Observatory.—Continued.

(Magnetometer U. S. C. and G. S. 20.)

Series	Date	Local mean time		Declination obtained*		C. I. W.—Tor.	Remarks
		From	To	C. I. W.	Toronto		
II	1906 Oct. 8	10 25	10 34	−5 46.5	−5 46 4	−0.1	
		12 32	12 41	52.9	52.1	−0.8	
		13 07	13 16	52.4	52.2	−0.2	
		15 42	15 51	46.5	49.1	?	
	10	9 15	9 24	42.1	43.2	+1.1	
		10 50	10 59	46.9	47.0	+0.1	
						0.0	P. E. = ±0′.21
Weighted mean value (C. I. W.—Tor.) from I and II +0′.1							P. E. = ±0′.1

* Same station throughout.

Results of Horizontal Intensity Comparisons at the Toronto Observatory.

(Magnetometer U. S. C. & G. S. 20.)

Series	Date	Local mean time		Horizontal intensity* obtained		C. I. W.—Tor. 48	Remarks
		From	To	C. I. W.	Toronto		
	1906	h m	h m	γ	γ	γ	
I	Sept. 5	11 59	13 27	16364	16376	−12	
		14 09	15 42	404	399	+ 5	
	6	10 37	12 03	355	364	− 9	
	8	10 08	11 24	357	361	− 4	
	10	9 21	10 40	343	359	−16	
		10 51	12 37	366	368	− 2	
						−6.3γ	P. E. = ±2.1γ
	1906						
II	Oct. 8	10 49	12 22	16357	16371	−14	
		13 42	15 27	383	386	− 3	
	9	9 43	11 04	372	374	− 2	
		11 58	13 12	371	380	− 9	
		13 58	15 07	377	386	− 9	
	10	9 32	10 42	374	380	− 6	
						−6.8γ	P. E. = ±1.2γ

Mean value (C. I. W.—Tor. $_{48}$) from I and II = −6.6γ ; P. E. = ±1.0γ
or −0.00040H ; P. E. = ±0.00007H

* The observations by 20 of Sept. 5 and 10, and of Oct. 9, 1906, were made on the regular intensity pier, I: those of Sept. 6 and 8, and Oct. 8 and 10, 1906, at the tent station T; all results are reduced to station I; I−T = +1.0γ.

Results of Inclination Comparisons at the Toronto Observatory (Agincourt).

(C. I. W. dip circle Dover 172.)

Series	Date	Local mean time From	Local mean time To	D. C. 172 needle	Inclination obtained* C. I. W.	Inclination obtained* Toronto	C. I. W.—Tor.	Remarks
	1906							
I	Sept. 6	14 40	15 24	I & 2	+74 36.4	+74 35.6	+0.8	172 at T; 130 at D
	7	13 36	14 27	I & 2	36.5	36.8	−0.3	172 at D; 130 at T
	8	13 27	14 11	I & 2	36.1	35.3	+0.8	172 at D; 130 at I
		14 27	15 23	I & 2	35.4	34.3	+1.1	" "
	10	13 36	14 23	I & 2	35.6	35.3	+0.3	" "
		13 44	13 50	I & 2	35.1	34.4	+0.7	172 at I; 130 at D
							+0.6	P. E. = ±0′.14
	1906							
II	Oct. 10	14 05	14 45	I & 2	+74 35.2	+74 35.2	0.0	172 at D; 130 at I
		15 09	16 01	I & 2	36.1	35.5	+0.6	172 at I; 130 at D
	11	9 21	10 05	I & 2	37.0	35.8	+1.2	" "
		10 22	11 11	I & 2	37.4	35.8	+1.6	172 at D; 130 at I
		13 48	14 32	I & 2	36.4	34.8	+1.6	" "
		15 02	15 44	I & 2	36.4	35.6	+0.8	172 at I; 130 at D
							+1.0	P. E. = ±0′.17

Mean value (C. I. W.—Tor.) from I and II = +0′.8; P. E. = ±0′.1

* There are no appreciable differences between the stations; I = observatory intensity pier; T = tent; D = observatory dip pier.

Results of Declination Comparisons by the Meteorological Service of Canada at the Toronto Observatory (Agincourt).

(C. I. W. magnetometer 8 for series I and Meteorological Service magnetometer 15 for series II.)

Series	Date	Mean 75th meridian time	Declination obtained C. I. W.	Declination obtained Toronto	C. I. W.—Tor.	Remarks
	1909	h m	° ′	° ′	′	
I	Oct. 29	12 51	−6 08.9	−6 06.0	−2.9	
		15 13	07.0	6 06.0	−1.0	
	Nov. 2	10 29	00.4	5 58.0	−2.4	
		12 21	05.0	6 04.0	−1.0	
		13 49	07.8	05.9	−1.9	
		15 23	05.9	04.5	−1.4	
	3	15 11	06.2	04.5	−1.7	
		15 21	06.0	04.3	−1.7	
					−1.7	P. E. = ±0′.2

Results of Declination Comparisons by the Meteorological Service of Canada at the Toronto Observatory (Agincourt).—Continued.

(C. I. W. magnetometer 8 for series I and Meteorological Service magnetometer 15 for series II.)

Series	Date	Mean 75th meridian time	Declination obtained		C. I. W.—Tor.	Remarks
			C. I. W.	Toronto		
	1910					
II	Apr. 21	13 06	—6 08.1	—6 08.1	0.0	
		15 12	07.5	07.3	—0.2	
	Sept. 28	15 11	07.6	03.5	—2.1	
		16 45	04.7	04.2	—0.5	
	29	10 36	18.4	17.8	—0.6	
		12 26	19.9	19.0	—0.9	
	Oct. 18	16 01	08.1	06.8	—1.3	
	19	10 48	10.3	09.0	—1.3	
		12 22	16.0	14.0	—2.0	
		13 32	14.0	13.2	—0.8	
		14 48	20.0	19.3	—0.7	
		15 20	18.7	17.8	—0.9	
		15 39	14.1	13.4	—0.7	
					—0.9	P. E. = ±0′.1

Weighted mean value (C. I. W.—Tor.) from I and II = — 1′.1; P. E. = ±0′.1

Results of Horizontal Intensity Comparisons by the Meteorological Service of Canada at the Toronto Observatory (Agincourt).

(C. I. W. magnetometer 8 for series I and Meteorological Service magnetometer 15 for series II.)

Series	Date	Mean 75th meridian time	Horizontal intensity obtained		C. I. W.—Tor. 98	Remarks
			C. I. W.	Toronto		
	1909	h m	γ	γ	γ	
I	Oct. 29	14 10	16294	16293	+ 1	
	Nov. 2	11 29	248	268	—20	
		14 36	270	398	—28	
					—15.7γ	P. E. = ±4.3γ
	1910					
II	Apr. 21	13 54	16268	16282	—14	
	Sept. 28	16 01	252	268	—16	
	29	11 50	184	194	—10	
	Oct. 19	11 42	202	213	—11	
		13 14	218	231	—13	
					—12.8γ	P. E. = ±0.7γ

Weighted mean value (C. I. W.—Tor. 98)
from series I and II = —12.9γ; P. E. = ±0.7γ.
or —0.00080H; P. E. = ±0.00004H.

Zi-ka-wei Observatory.

Both series of observations at Zi-ka-wei were made at the regular magnetic hut or absolute house of the Observatory and at a second station, *N*, distant 21.3 meters in a direction 6° west of north from the hut pier. Suitable interchanges of stations and instruments were made for both series. In the work of September, 1907, there were no dip data obtained sufficient for discussion. The differences of May, 1907, depend upon directly observed values of declination, horizontal intensity, and dip, simultaneously by the standard observatory instruments, viz.: Elliott magnetometer 49, and Dover dip circle 33 (needle 14); those of September, 1907, upon readings of the magnetograms standardized by the same absolute instruments.

Results of Declination Comparisons at Zi-ka-wei Observatory.

(C. I. W. Magnetometer 1 for Series I and 2 for Series II.)

Series	Date	Local mean time		Declination obtained*		C. I. W.—Z	Remarks
		From	To	C. I. W.	Zi-ka-wei		
	1907	h m	h m	° ′	° ′	′	
I	May 14	10 03	10 12	−2 32.9	−2 32.0	−0.9	1 at N.
		11 29	11 38	35.5	35.4	−0.1	
	15	10 44	10 54	35.7	34.1	−1.6	
		11 56	12 05	38.3	36.6	−1.7	
	14	13 57	14 07	−2 37.5	−2 36.2	−1.3	1 at H.
		15 18	15 27	35.6	35.1	−0.5	
						−1.0	P. E. = ±0′.2
	1907						
II	Sept. 11	15 01	15 14	−2 36.1	−2 35.2	−0.9	2 at N.
		17 28	17 38	35.2	34.5	−0.7	
	12	15 00	15 13	36.5	35.3	−1.2	
	11	9 39	9 50	−2 36.3	−2 34.8	−1.5	2 at H.
		12 04	12 16	38.3	37.4	−0.9	
						−1.0	P. E. = ±0′.1

Mean value (C. I. W. — Z) from I and II = −1′.0; P. E. = ±0′.1

* All values reduced to hut, H (H − N = + 1′.4); N is north outside station.

Results of Horizontal Intensity Comparisons at Zi-ka-wei Observatory.

(C. I. W. magnetometers 1 for series I and 2 for series II.)

Series	Date	Local mean time From	Local mean time To	Horizontal intensity* obtained C.I.W.	Horizontal intensity* obtained Zi-ka-wei	C.I.W.—Z.	Remarks
	1907	h m	h m	γ	γ	γ	
I	May 14	10 20	11 20	33036	32997	+39	1 at N; 49 at H
		14 12	15 12	3087	3061	+26	1 at H; 49 at N
	15	10 55	11 54	3081	3071	+10	1 at N; 49 at H
						+25.0γ	P. E. = ±7.1γ
	1907						
II	Sept. 11	11 28	12 30	33099	33073	+26	2 at N; quarter set, weight ¼
		16 16	17 22	3058	3044	+24	Half set; weight ½
	12	15 17	17 28	3014	2998	+16	
	12	9 56	12 00	3022	3006	+16	2 at H; half set, weight ½
						+18.9γ	P. E. = ±1.0γ

Weighted mean value (C. I. W.—Z.) from I and II = +19.0γ; P. E. = ±1.0γ
or +0.00058H; P. E. = ±0.00003H

* All values reduced to station hut, H (H—N = −14γ); N is north outside station.

Results of Inclination Comparisons at the Zi-ka-wei Observatory.

(C. I. W. dip circle Dover 178.)

Date	Local mean time From	Local mean time To	D. C. 178 needle	Inclination obtained* C. I. W.	Inclination obtained* Zi-ka-wei	C. I. W.—Z. Needle 1	C. I. W.—Z. Needle 2	Remarks
1907	h m	h m		° ′	° ′	′	′	
May 14	16 00	16 46	1	+45 38.7	+45 40.9	−2.2		178 at N; 33 at H
	16 09	16 35	2	38.8			−2.1	
18	11 03	11 29	1	36.3	37.0	−0.7		
	11 08	11 21	2	37.5			+0.5	
May 18	8 56	9 33	1	+45 36.5	+45 37.8	−1.3		178 at H; 33 at N
	9 03	9 23	2	36.8			−1.0	
					Means	−1.4	−0.9	

Mean value (C. I. W.—Z.) = −1′.1; P. E. = ±0′.3

*All results reduced to hut station, H (H—N = +0′.4); N = north outside station.

Carnegie Institution of Washington,
Department of Terrestrial Magnetism.

(To be continued.)

DATA FOR ABRUPTLY BEGINNING MAGNETIC DISTURBANCES, 1906–1909, No. I.

Reports from Greenwich, Agincourt, Stonyhurst, Uccle, Potsdam, Wilhelmshaven, München, Ekaterinburg, Pola, Helwan, Porto Rico, Cheltenham, Baldwin, Sitka, Honolulu, Bombay, and Val Joyeux.

In order to obtain additional data on the question of simultaneity of abruptly beginning magnetic disturbances, the following letter was sent to all magnetic observatories in operation during the period concerned:

CARNEGIE INSTITUTION OF WASHINGTON

DEPARTMENT OF RESEARCH IN TERRESTRIAL MAGNETISM

THE ONTARIO, WASHINGTON, D. C., *December 20, 1911.*

THE DIRECTOR, MAGNETIC OBSERVATORY:

DEAR SIR,—Kindly supply this office with the Greenwich mean civil times for your Observatory of sudden beginnings of the fifteen magnetic disturbances tabulated by Mr. R. L. Faris in *Terr. Mag.*, Vol. XV, p. 101; please note No. 4 should be Feb. 9, 1907, instead of Feb. 7, and Nos. 13, 14, 15 refer to 1909. The time should be determined separately with all possible accuracy for each magnetic element registered at your Observatory, a specimen calculation being added and a full statement made as to corrections applied. An estimate of the possible error should be attached to each time scaling.

If not too much trouble, it will be desirable to give also the disturbance effect (direction and amount) for each element by taking the difference in the ordinates between the beginning and the first sharp turning point and applying whatever corrections may be necessary. It is quite possible that this may present difficulties in some cases, and you will, of course, be obliged to use your own judgment as to what is wanted. The approximate time interval between the two ordinates will likewise be useful.

Similar data to the above are being requested of other observatories for publication in the journal "Terrestrial Magnetism and Atmospheric Electricity."

Your early attention to above requests will be much appreciated.

Very truly yours,

L. A. BAUER, *Director.*

The Reports received to date (March 4th) are given in this number in the order received. The occasion is embraced to express to the various contributing directors the sincere appreciation of the Department of the promptness and readiness with which the desired data are being supplied. It is hoped that the remaining reports may be published in the September issue, and the final com-

pilation and discussion soon thereafter. By publishing the communications in the form as received opportunity is afforded others to make independent investigations of their own. L. A. B.

ROYAL OBSERVATORY GREENWICH, JANUARY 13, 1911.

Greenwich mean civil times of beginnings of magnetic storms (1906—1909), discussed by Mr. R. L. Faris, with approximate amplitude of initial spasmodic movements and time intervals when exceeding a minute.

The times, etc., are from photographic sheets with hour breaks simultaneously made by time break clock. No confidence can be placed in times given with greater accuracy than minutes.

F. W. DYSON, *Astronomer Royal.*

No.	Disturbance	D (Declination)	H (Horizontal Intensity)	Z (Vertical Intensity)
		h m	h m γ	h m γ
1	1906, July 29, (a)	19 57, (+1′—1′)	19 57, (—9+65)	19 57, (+9)
2	Aug. 7, (a)	13 35, (+2′), 5m	13 34, (+24) 7m	13 35, (very slight)
3	Dec. 21, (a)	21 31, (—6′), 8m	21 30, (+45) 4m	21 33, (slight)
4	1907, Feb. 9, (b)	14 14, (—1′+5′)	14 14, (—19+63)	14 14, (—4+17)
5	July 10, (a)	14 23, (—1′+3′), 4m	14 23, (+35)	14 23, (slight)
6	Oct. 13, (a)	7 44, (+1′—3′)	7 44, (+6—13)	7 44, (+4—4)
7	1908, Mar. 26, (b)	17 43, †	17 43,†	17 43, (+9), 5m
8	Aug. 19, (a)	0 15, (+5′)	0 15, (+41)	0 16, (+4), 3m
9	Sept. 11, (a)	7 20, (+1′—4′)	7 20, (+11—33)	7 21, (—4)
10	Sept. 11, (b)	21 47, (+2′—11′)	21 47, (+130)	21 48, (+17)*
11	Sept. 28, (a)	8 42, (+1′—3′)	8 42, (+6—24)	8 42, (—4)
12	Sept. 29, (b)	1 33, (—2′+9′)	1 33, (—9+79)	1 34, (+13)
13	1909, May 14, (a)	4 58, (+24′), 15m	4 58, (+37) 5m	4 58, (+9)
14	Sept. 25, (a)	8 30, ‡ (—2′)	8 30‡, (—13)	8 30, (slight)
15	Sept. 25, (b)	11 40+, ⸮ (—75′)	11 40+⸮, (*)	11 40,+, ⸮ (—61)

* By the end of two hours, *Z* had diminished about 500 units and gone out of range.

† Twitch superposed on wave. Can not be relied on as beginning.

‡ Sharp wave at 8h 42m can not be taken as beginning. Suggest re-examination of American curves.

⸮ Actual beginning took place while lights were cut off for identification of hour-breaks on photographic registers.

(*) *H* decreased by some hundreds of units and went out of range.

ADDITIONAL INFORMATION, *March 1, 1911.*

In reply to your letter dated February 17, I have to inform you that your interpretation of the plus (+) signs in our statement of January 13 is quite correct, viz: increase of west declination and of horizontal and of vertical force.

The additional data in regard to No. 14 are as follows, with the same headings, etc., as before:

	D	H	Z
	h m	h m	h m
1909 Sept. 25	8 40 (—1′+4′)	8 40 (+22γ)	8 40 (+4γ)

The *Z* movement is small and the *H* movement is not a characteristic one, being simply a sharp wave. The *D* movement is quite characteristic at first, but becomes a very sharp wave immediately after the first eastward jerk. F. W. DYSON, *Astronomer Royal.*

MAGNETIC OBSERVATORY, AGINCOURT, CANADA, JANUARY 23, 1911.

I have pleasure in transmitting herewith the information requested in your letter of the 20th ultimo. I attach Mr. Mengies' report to me. The value of one millimeter ordinate horizontal intensity was 5γ. R. F. STUPART, *Director.*

AGINCOURT, *January 12, 1911.*

I enclose the information asked for by L. A. Bauer as far as I understand the request. I do not know the shape in which to tabulate in order to suit Mr. Bauer, but as you will see I have scaled the times as accurately as I could with the aid of scale in hundredths of inch. I have given an approximate time from the initial movement to apex of same together with amplitudes in minutes and millimetres. I scaled the times as per the following example:

	inch.		
Measured hour of occurrence	.730	Oct. 13, 1907.	D at 7 hrs. G. M. T.
" to time of "	.520		
	m	m s	
.730 : .520 ::	60 :	42 44·4	
		—9·7	Cut off slow
		7 42 54·1 =	
		7 42·90	Corrected time

I went to seconds for application of interpolated error of cut-off. I will not attempt to give a probable error but may say that cut-off varies at different hours to extent of half a second and comparison is made at noon of each day. My measurements were made as closely as possible. Variations of intensity in trace would, I think, be responsible for greatest source of error.

The plus (+) sign signifies an increase of westerly declination and increase of *H*. W. MENGIES.

Greenwich Mean Civil Times of Sudden Beginnings of Magnetic Storms.

No.	Year	Day of Month	D (DECLINATION)			H (Horizontal Intensity)			Remarks
			Times of Beginning	Approx. time from initial movement to first Apex	Amplitude and direction	Times of Beginning	Approx. time from initial movement to Apex	Amplitude and direction	
			h m	m	′	h m	m	mm	
1	1906	July 29th	19 55.59	0.5	+ 4.0	19 56.31	1.0	— 3.0	(a)
2		Aug. 7th	13 39.89	2.0	— 1.5	13 40.26	0.0	+ 1.8	(a)
3		Dec. 21st	21 30.98	2.0	+ 4.0	21 30.98	1.0	— 2.5	(a)
4	1907	Feby. 9th	14 13.03	0.0	— 2.7	14 12.51	0.0	+11.0	(b)
5		July 10th	14 24.73	0.0	— 1.5	14 22.47	0.0	+ 4.2	(a)
6		Oct. 13th	7 42.90	2.0	— 1.2	7 43.25	2.0	+ 4.3	(a)
7	1908	Mar. 26th	17 42.07	1.0	+ 3.0	17 42.84	3.0	— 9.0	(b)
8		Aug. 19th	0 14.42	5.0	+ 4.5	0 14.21	1.0	— 1.2	(a)
9		Sept. 11th	7 20.73	1.5	— 1.5	7 21.06	3.0	+ 4.5	(a)
10		Sept. 11th	21 47.73	0.0	— 4.5	21 47.74	0.0	+30.0	(b)
11		Sept. 28th	8 41.78	2.0	— 2.0	8 41.79	3.0	+ 3.0	(a)
12		Sept. 29th	1 30.97	1.0	+ 6.0	1 30.27	2.0	— 4.0	(b)
13	1909	May 14th	4 57.79	6.0	—11.0	4 57.29	2.0	+21.0	(a)
14		Sept. 25th	8 37.31	2.0	— 2.2	8 38.70	3.0	+ 3.3	(a)
15		Sept. 25th	11 39.73	1.0	—11.2	11 41.45	0.0	+31.5	(b)

STONYHURST COLLEGE, BLACKBURN, JANUARY, 1911.

Our magnetograph is not fitted with automatic time shutter. The lights are cut off at 4 P. M. and 10 A. M. and occasionally at other hours.

The times quoted have been carefully taken by mm. scale and proportion. I consider them safe to about ½ minute.

No. 14 has puzzled me. I have worked the times from several fiducial hours; and can only get the values in the columns by supposing a second move to have been taken as the beginning, by the other observatories.

The signs +, signify westward declination, or less force;

1 mm. $D = 1.128'$ arc; 1 mm. $H = 5\gamma$; 1 mm. $Z = (?)$

W. SIDGREAVES, *S. J.*

Stonyhurst Magnetic Observatory.

No.	Date	Magnetic Element	Greenwich mean civil time	Displacement			Total Displacement
			h m	mm	mm	m	mm
		D	19 55.8	— 1	in	1	1.0
1	1906 July 29	H	55.7	— 2.5	to +15	1½	17.5
		Z	.....	.....		.....	.....
		D	13 37.5	+ 2		6	2
2	Aug. 7	H	37.5	+ 5		4	5
		Z	.....	.....		.....	.....
		D	No sharp	move.			
3	Dec. 21	H	21 28.1	+ 8		½	8
		Z	.....	.....		.....	.....
		D	14 15.6	+ 7		4	7
4	1907 Feb. 9	H	15.1	+10		1	10
		Z	.....	.....		.....	.....
		D	14 22.5	— 1	to + 3	4	4
5	July 10	H	22.5	+ 6		1	6
		Z	22.5	— 1			1
		D	7 43.1	+ 3.5	to — 4.2	4	7.7
6	Oct. 13	H	42.7	+ 5	— 2	2	7
		Z	.....	.....		.....	.....
		D					
7	1908 Mar. 26	H	(Curve in	London).			
		Z					
		D	0 12.2	+ 6		4	6
8	Aug. 19	H	11.6	+ 9		4	9
		Z	12.7	(Slow).			
		D	7 17.4	+ 2	to — 4	4	6
9	Sept. 11	H	17.8	.....	.....	.....	.....
		Z	.....	.....	.....	.....	.....
		D	21 44.8	—14		12	14
10	Sept. 11	H	45.2	+30		1	30
		Z	44.8	— 6.5		2	6.5
		D	8 41.6	+ 2	to — 2	1	4.0
11	Sept. 28	H	41.2	+ 2	to — 4.2	2	6.2
		Z	41.6	(Very Small).			
		D	1 31.1	— 3	to + 8.5	2	11.5
12	Sept. 29	H	34.0	— 2	to +15.5	2	17.5
		Z	34.1	.....		.....	.....
		D*	.....	.....	.....	.....	.....
13	1909 May 14	H	4 54.3	+17		6	17
		Z*	.....	.....		.....	.....
		D	8 32.6†	— 2.5		1	2.5
14	Sept. 25	H	29.0†	— 3.5		1	3.5
		Z	.....	.....		.....	
		D					
15	Sept. 25	H	(During C	hange).			
		Z					

* *D* and *Z* out of action. † See statement in text above.

OBSERVATOIRE ROYAL, BELGIQUE, UCCLE, 20 JAN., 1911.

En réponse à votre lettre du 20 Décembre, 1910, j'ai l'honneur de vous faire parvenir les renseignements ci-annexés.

G. LECOINTE,

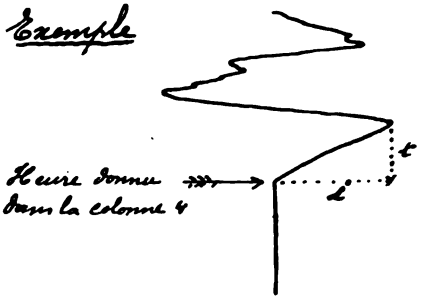
Le Directeur scientifique du Service astronomique.

No.	DATES	Eléments magnétiques	Commencement brusque des perturbations en temps civil de Greenwich	Erreur probable des relevés indépendamment de la corr. de la pendule	Sens de la déviation	t	i	REMARQUES
			h m	m		m		
1	1906 29 Juillet	D	.....	....	.....	.....	.....	
		H	19 57.0	±0.5	+	3.0	40γ	
2	7 Août	D	13 40.7	1.0	W	3.0	1′.3	
		H	13 39.5	1.0	+	5.4	18γ	
3	21 Décembre	D	21 31.8	0.5	E	12.8	6′.2	
		H	21 32.9	0.5	+	3.1	36γ	
4	1907 9 Fevrier	D	14 13.5	0.5	E	2.3	5′.0	
		H	14 11.6	0.5	+	1.2	32γ	
		Z	14 12.8	0.5	+	1.5	15γ	
5	10 Juillet	D	14 22.8	0.5	W	3.0	2′.3	
		H	14 22.4	0.5	+	5.4	34γ	
6	13 Octobre	D	7 43.4	0.5	E	2.3	2′.0	
		H	7 46.8	1.0	+	5.0	8γ	
7	1908 26 Mars	D	17 29.0[1]	1.0	E	49.0	17′.8	
		H	17 40.7[2]	0.5	+	13.5	48γ	
8	19 Août	D	0 13.5	0.5	W	3.0	4′.4	
		H	0 14.3	0.5	+	4.6	32γ	
9	11 Septembre	D	7 20.9	0.5	E	3 1	2′.9	
		H	7 21.3	0.5	—	3.1	6γ	
10	11 Septembre	D	21 48.4	0.5	E	8.1	8′.6	
		H	21 44.9	0.5	+	3.1	110γ	
		Z	21 46.5	0.5	+	<1.0	11γ	
11	28 Septembre	D	8 42.2	0.5	E	<1.0	1′.9	
		H	8 42.6	0.5	—	<1.0	8γ	
12	29 Septembre	D	1 32.1	0.5	E	<1.0	1′.9	
		H	1 32.1	0.5	+	1.9	49γ	
		Z	1 32.1	0.5	+	1.5	12γ	
13	1909 14 Mai	D	4 56.1	0.5	W	17.4	23′.5	
		H	4 54.6	0.5	+	7.7	57γ	
		Z	4 56.9	0.5	+	4.3	18γ	
14	25 Septembre	D	8 39.7	0.5	W	5.0	2′.7	
		H	8 38.6	0.5	+	4.3	15γ	
		Z	8 39.7	0.5	+	5.8	12γ	
14 a	25 Septembre	D	8 31.0	0.5	E	2.7	1′.7	
		H	8 31.0	0.5	—	2.3	10γ	
15	25 Septembre	D	11 43.4	1.0	E	(?)	(?)	
		H	11 41.4	0.5	—	11.6	354γ	
		Z	11 42.6	1.0	—	(?)	(?)	

Correction de la pendule de l'enregistreur.

Comme on se borne à remettre celle-ci à l'heure lorsque l'on constate une avance ou un retard d'une minute environ, sa correction varie donc entre o et ± 1 minute.

Le temps est repéré sur les courbes, toutes les deux heures. Le déplacement du papier sensible est de 15.5 m/m par heure.



Dans la colonne 6, le signe + signifie que la déviation brusque a lieu dans le sens d'une augmentation pour l'élément correspondant et le signe (—) qu'élla a en lieu dans le sens d'une diminution.

Dans la derniére colonne, D est donné en minutes d'arc, H et Z en unité C. G. S.

Nos appareils sont influencés par les tramways électriques. L'épaisseur des courbes varie entre 1 et 3 millimetres.

O. SOMVILLE.

1 à $17^h\ 29^m$ déviation lente vers l'Est.

2 à $17^h\ 40.7^m$ il y a une déviation brusque, mais la perturbation commence raisemblablement par une première déviation à $17^h\ 21^m$.

KAISERLICHES OBSERVATORIUM, WILHELMSHAVEN, 20. JAN. '11.

Unter Bezugnahme auf Ihre werte Zuschrift vom 20. December 1910 erlaube ich mir, Ihnen in der Anlage die gewünschten Angaben zuzustellen. Die Zeiten sind auf 1 Minute genau; in Zukunft wird es mir möglich sein, sie auf eine halbe Minute genau anzugeben. CAPELLE, *Korvetten-Kapitän a. D.*

No.	Date	Magnetic Element	Greenwich Mean Civil Times h m
1	1906 July 29	D	19 55.4
		H	56.4
2	Aug. 7	D	13 38.9
		H	39.9
3	Dec. 21	D	21 41.4 (?)
		H	31.4
4	1907 Feb. 9	D	14 10.4
		H	10.4
5	July 10	D	14 20.4
		H	21.9
6	Oct. 13	D	7 39.9
		H	41.4
7	1908 Mch. 26	D	17 42.4 (?)
		H	40.4 (?)
8	Aug. 19	D	0 12.4
		H	15.4
9	Sept. 11	D	7 20.4
		H	19.9
10	Sept. 11	D	21 47.4
		H	46.4
11	Sept. 28	D	8 40.4
		H	41.4
12	Sept. 29	D	1 29.9
		H	31.4
13	1909 May 14	D	4 56.4
		H	49.4 (?)
14	Sept. 25	D	8 36.9
		H	38.4
15	Sept. 25	D	11 39.4
		H	?

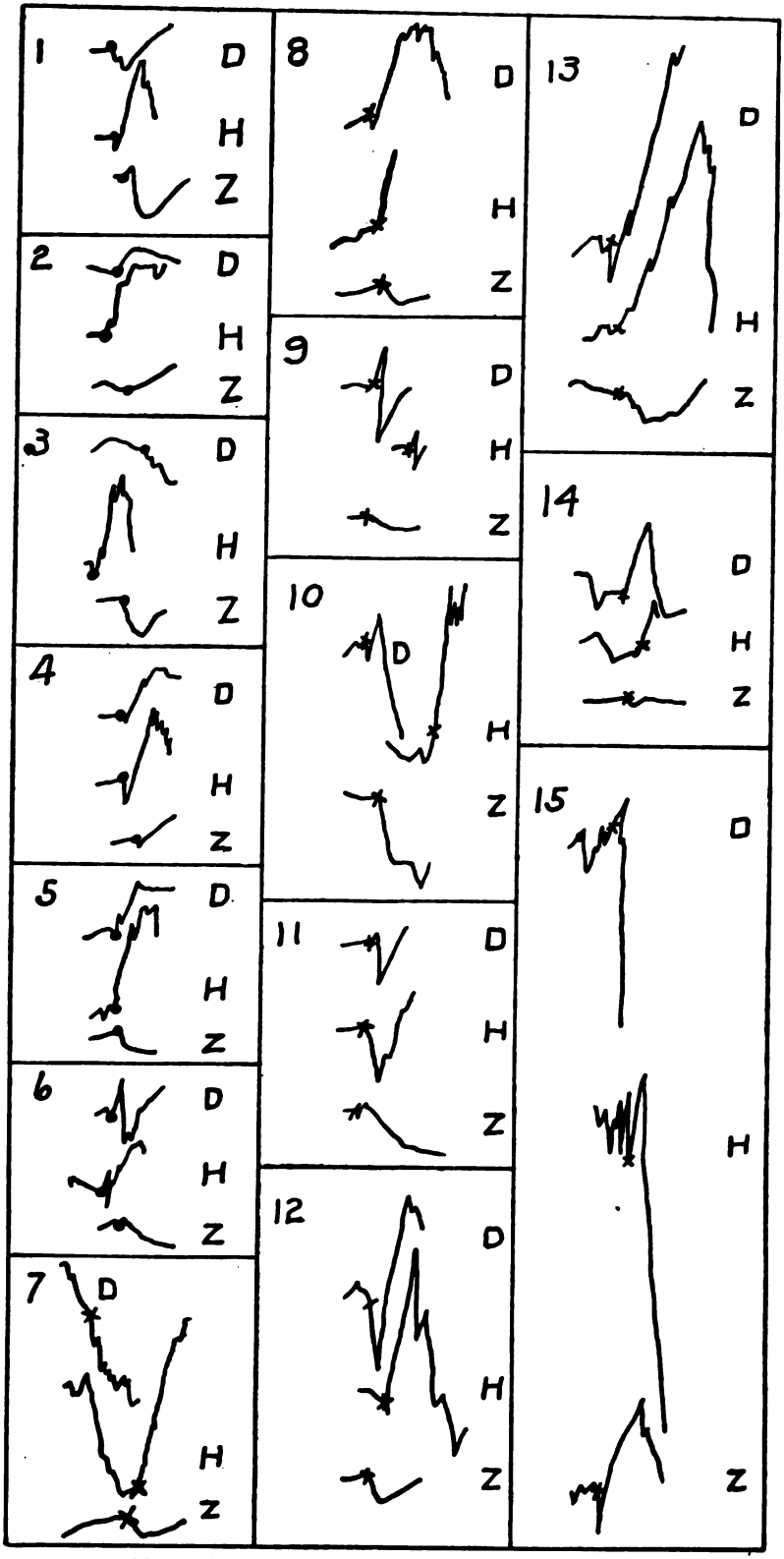
METEOROLOGISCH MAGNETISCHES OBSERVATORIUM, POTSDAM, 20. JANUAR 1911.

Die umstehend angegebenen Greenwicher Zeiten für den Ausbruch der in Ihrem Schreiben v. 20, XII, 10 bezeichneten Störungen habe ich nach den Curven des Potsdamer Magnetographen festgestellt. Dabei wandte ich folgendes Verfahren an. Ich entnahm den laufenden Aufzeichnungen über die Ablesungen am Kontroll-System die Zeit *S* des Schirmfalles nach der Beobachtungsuhr E 821. Zu dieser Zeit, *S*, addirte ich den Zeitunterschied

D, des Störungsausbruches gegen den Schirmfall. Die so gefundene Zeit, $S+D$, corrigirte ich durch Hinzufügung des Betrages P der Parallaxe. Indem ich weiter zu der Uhrzeit $S+D+P$ die Correktion $\triangle$ von E 821 nach Greenwicher Zeit hinzufügte, erhielt ich die Greenwicher Zeit des Störungsausbruches. Der Fehler dieser Zeit ist auf etwa 1 Minute zu schätzen. Welcher Punkt der Curve als Ausbruch der Störung angesehen ist, habe ich jeweils durch die beigefügten Skizzen kenntlich gemacht. VENSKE.

Störungsausbrüche nach Greenwicher Zeit.

No.	Tag	Element	S	D	P	S+D+P	Δ	Gr. Zeit
			h m	m	m	h m	m	h m
1	1906 Juli 29	D	18 57.1	56.1	1.4	19 54.6	+2.9	19 57.5
		H		55.7	0.8	53.6		56.5
		Z		54.7	2.0	53.8		56.7
2	Aug. 7	D	12 56.9	38.0	1.6	13 36.5	+3.1	13 39.6
		H		37.0	0.5	34.4		37.5
		Z		37.7	2.0	36.6		39.7
3	Dec. 21	D	20 54.4	29.7	1.3	21 25.4	+5.6	21 31.0
		H		29.0	1.0	24.4		30.0
		Z		30.7	1.3	26.4		32.0
4	1907 Febr. 9	D	14 5.4	12.5	0.0	14 17.9	−5.5	14 12.4
		H		11.5	1.0	17.9		12.4
		Z		12.0	2.0	19.4		13.9
5	Juli 10	D	14 3.1	22.5	0.8	14 26.4	−3.1	14 23.3
		H		22.0	1.2	26.3		23.2
		Z		22.6	2.0	27.7		24.6
6	Oct. 13	D	7 1.7	40.0	2.0	7 43.7	−1.6	7 42.1
		H		41.9	1.7	45.3		43.7
		Z		41.9	1.3	44.9		43.3
7	1908 März 26	D	17 4.0	40.4	2.0	17 46.4	−4.0	17 42.4
		H		39.8	1.5	45.3		41.3
		Z		40.0	1.5	45.5		41.5
8	Aug. 19	D	0 1.4	12.0	2.0	0 15.4	−1.4	0 14.0
		H		13.0	1.5	15.9		14.5
		Z		13.8	2.0	17.2		15.8
9	Sept. 11	D	7 1.0	18.4	1.8	7 21.2	−1.1	7 20.1
		H		19.3	1.5	21.8		20.7
		Z		19.8	1.5	22.3		21.2
10	Sept. 11	D	21 1.1	44.4	2.0	21 47.5	−1.1	21 46.4
		H		45.2	2.4	48.7		47.6
		Z		45.6	1.8	48.5		47.4
11	Sept. 28	D	8 0.8	38.5	2.0	41.3	−0.8	8 40.5
		H		40.8	1.8	43.4		42.6
		Z		41.5	1.5	43.8		43.0
12	Sept. 29	D	1 0.8	30.2	2.0	1 33.0	−0.8	1 32.2
		H		30.2	1.8	32.8		32.0
		Z		31.2	1.5	33.5		32.7
13	1909 Mai 14	D	4 2.2	54.0	2.0	4 58.2	−2.2	4 56.0
		H		54.0	1.8	58.0		55.8
		Z		55.8	1.8	59.8		57.6
14	Sept. 25	D	7 59.8	36.4	1.9	8 38.1	+0.2	8 38.3
		H		35.8	2.0	37.6		37.8
		Z		36.7	1.8	38.3		38.5
15	Sept. 25	D	10 59.8	39.1	1.9	11 40.8	+0.2	11 41.0
		H		39.0	2.0	40.8		41.0
		Z		40.3	1.8	41.9		42.1



Magnetische Störungen, Potsdam Observatorium.

ERDMAGNETISCHES OBSERVATORIUM, MÜNCHEN, 25. JAN. 1911.

Anbei beehre ich mich, Ihnen die Ablesungen der gewünschten Curven zu senden. Die Zeiten sind auf etwa ±0.7 Minuten genau; die Beträge der Ablenkungen ±0′.2 bez. 2γ und die Dauer der ersten Ausweichungen ±0.5 Min. Die Zunahme der westlichen Declination, bez. der Horizontalintensität ist mit ∧ bezeichnet, die Abnahme mit ∨. Ich habe bei den Ablesungen immer diejenigen Wendepunkte bez. Einsätze abgelesen, welche den Zeiten des Herrn Faris am nächsten lagen. In manchen Fällen machte ich 2 Ablesungen, die ich dann durch eine kleine Skizze der Curve ergänzte. Die Wage (Z) ist ausser Betrieb wegen elektrischer Störungen.

N. B.: 48° 8′.8; E. L. Green.: 11° 36′.5; Höhe 529 m.

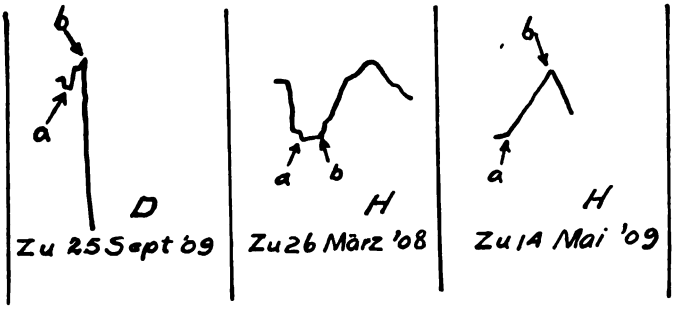
J. B. MESSERSCHMITT.

Addendum, 6. April, 1911. Es findet sich am 11. Juli fruh 5^h 44.8^m noch ein scharfer Zacken, dessen Zeit ich gebe, die Ihnen vielleicht von Nutzen sein kann.—J. B. M.

No.	Date	D (Declination)		H (Horizontal Intensität)	
		Zeit u. Richtung	Betrag und Dauer	Zeit u. Richtung	Betrag und Dauer
		h m	′ m	h m	γ m
1	1906 July 29	19 57.1 ∨	1.2 in 2.6	19 56.3 ∧	39 in 3.0
2	Aug. 7	13 39.5 ∧	1.5 4.0	13 39.5 ∧	14 9.0
3	Dec. 21	20 6.7 21 30.2 ∨	4.3 10.0	21 30.6 ∧	43 7.5
4	1907 Feb. 9	14 12.3 ∧	3.8 4.0	14 12.0 ∧	22 2.0
5	July 10	14 23.2 ∧	2.7 5.0	14 20.6 ∧	26 1.3
6	Oct. 13	7 44.0 ∧	1.2 0.1	7 39.0 (a) 45.0 (b) } ∧	13 7.0
7	1908 Mch. 26	17 30.0* 42.0 ∨	15.1 48.0	17 36.5 (a) 40.5 (b) } ∧	31 4.5
8	Aug. 19	0 15.2 ∧	4.5 4.0	0 14.9 ∧	30 5.5
9	Sept. 11	7 20.0 ∨	2.6 3.0	7 22.5 ∧	5 3.0
10	Sept. 11	21 46.5 ∧	1.4 0.6	21 46.0 ∧	>90+ 0.1
11	Sept. 28	8 41.1 ∨	1.2 2.5	8 42.8 ∧	4 0.1
12	Sept. 29	1 32.2 ∨	2.5 0.6	1 32.4 ∧	47 2.8
13	1909 May 14	4 55.7 ∧	12.2 4.5	4 51.2 (a) 58.7 (b) } ∧	51 7.0
14	Sept. 25	8 38.9 ∧	3.2 2.5	8 38.5 ∧	9 0.1
15	Sept. 25	11 38.9 (a) 43.9 (b) } ∨	64.7 15	11 39.0 ∨	261 12

* Ganz flacher Abfall ohne deutlichen Einsatz.

† Der Endpunkt liegt ausserhalb des Papierrandes.



Magnetische Störungen, München Observatorium.

OBSERVATORIUM IN EKATERINBURG, 10.–23. JAN. 1911.

$\gamma = 56°49'38''.3$; $\lambda = 60°38'13''.5$ E. v. Gr. $= 4^h\,2^m33^s$ E. v. Gr.

In Folge Ihres Circulars vom 20. December 1910 sende ich Ihnen beiliegend die gewünschten Ausmessungen und Berechnungen über die von Ihnen genannten 15 magn. Störungen.

Die Bestimmung von Zeitmomenten auf den Curven des Magnetographen unseres Observatoriums ist selbstverständlich nicht mit grosser Genauigkeit möglich, obgleich bei unserem Magnetographen—Wild Edelmann—die Zeitmarken zweistündlich erfolgen, weil nämlich das Stundenintervall nur etwa 15 mm umfasst. Die Zeitmarken entstehen dadurch, dass die Walzen mit dem photographischen Papier jede 2 Stunden um 1 mm weiterspringen, jedoch sind diese Zwischenräume auf den Curven nicht scharf markirt, da wegen der nicht völligen Ebenheit der Magnetometerspiegel und der relativen Grösse des Lichtpunktes photographische Wirkungen auch an beiden Rändern der Zwischenräume in den Curven entstehen; auf den Normallinien jedoch sind diese Ungenauigkeiten nicht vorhanden, die beiden Ränder der Zwischenräume sind völlig scharf.

Die Uhr des Magnetographen ist möglichst genau regulirt und wird täglich mit einer Normalpendeluhr mit Pendel von Riefler verglichen, deren Correction bekannt ist. Wenn auch specielle Vergleiche beider Uhren eine Verschiedenheit im täglichen Gange nicht ergeben, so ist aber bisweilen dennoch eine Differenz beobachtet worden.

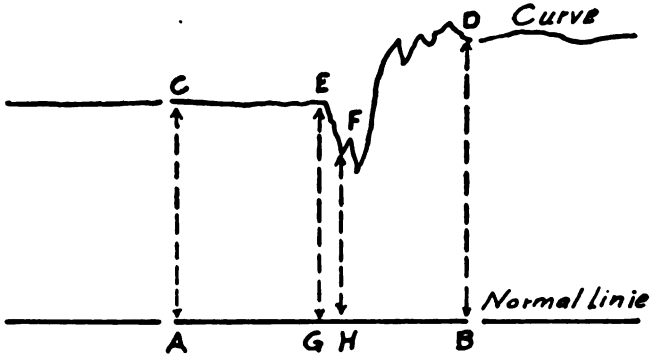
Die Länge des Intervalls von 2 Stunden auf der Normallinie dient mir als Mass für die entsprechende Länge auf der Curve, da sie die Horizontalprojection der Curven bildet. Diese Länge variirt zwischen 29 und 31 mm wegen der Ungleichheit von Zähnen des Rades, welches das Überspringen der Walzen bewirkt. Bei der Länge von 29 mm pro 120 Minuten entspricht 0.1 mm einem Werte von 26 Sec. oder 0.43 Minuten und bei der Länge von 31 mm pro 120 Minuten entspricht der Grösse 0.1 mm ein Wert von 24 Sec. = 0.4 Minuten.

Nun erscheint es mir doch recht fraglich, ob auf den Curven

die Eintrittszeiten von Störungen mit einer Genauigkeit von 0.1 mm abgelesen werden können, zumal die Breite unserer Curven zwischen 0.5 mm und 1.0 mm schwankt und bei plötzlichen Richtungsänderungen nicht immer die Stelle der Knickung deutlich erkannt werden kann.

Nach Obigem glaube ich annehmen zu dürfen, dass die Genauigkeit von Zeitmomenten, die unseren Curven entnommen werden sollen, keinesfalls grösser als ±0.5 Min. angesetzt werden darf und bisweilen sogar ±1 Min. beträgt.

Um die gewünschten Eintrittszeiten der Störungen und der ersten Umkehrpunkte zu finden, messe ich mit Hilfe einer Millimeterglasscala, die senkrecht auf die Richtung der Normallinie gelegt wird, die Länge des Stückes der Normallinie zwischen zwei Zeitmarken und auf der Curve die zugehörige projicirte Länge des Curventheils, die wegen der oben erwähnten photographischen Wirkungen an den Enden grösser ist als die auf der Normallinie; die halbe Differenz dieser beiden Längen ziehe ich dann vom Anfangsende des Curvenstücks ab und gewinne so den Anfangspunkt nach der Zeitmarke, welcher einer graden Stunde +10 Min. entspricht. Die weitere Ausführung der Ermittelung der gewünschten Zeitmomente, die Anbringung der verschiedenen Correctionen und Reductionen zeigt wohl am besten das folgende Beispiel für die magnetische Störung vom 14. Mai 1909 für die Declination und deren schematische Zeichnung:



1. Länge des 2 Stundenintervalls auf der Normallinie:

$$AB = a = 29.9 \text{ mm}.$$

2. Länge der Projection des Curvenstücks: $CD = b = 30.5$ mm.

3. Entfernung des Anfangs der Störung vom Anfangspunkt des Curvenstücks: $CE = c = 12.8$ mm ± 0.2.

4. Entfernung des ersten Umkehrpunkts der Störung vom Anfangspunkt des Curvenstücks: $CF = d = 13.1$ mm ± 0.1.

5. Corrigirte Länge des Curvenstücks von seinem Anfangspunkt bis zum Anfang der Störung:

$$c - \frac{(b-a)}{2} = e = 12.5 \text{ mm}.$$

TABLE I. *Berechnung der Zeitmomente.*

No.	Dat.	El.	a	b	c	d	e	f	g	h	u	u₁	u + u₁	u + u₁	U	U+u +u₁	+U−u +u₁−s	x	y	m	n	n—m	n—m
			mm	mm	mm	mm	mm	mm	min.	min.	sec.	sec.	sec.	min.	h m	h m	h m	h m m	h m m	mm	mm	mm	′
1	1906 Juli 29	D	29.3	29.6	27.1 ±0.1	27.3 ±0.1	27.0	27.2	110.6	111.1	− 2	− 3	− 5	−0.1	22 10.0	22 9.9	18 7.4	19 58.0 ±0.4	19 58.5 ±0.4	101.5	97.3	−4.2	4.2 W
		H	29.2	30.0	27.0 0.2	27.6 0.1	26.6	27.2	109.3	111.8								56.7 0.8	59.2 0.4	98.2	106.2	8.0	40γ
		Z	28.9	29.1	26.8 0.1	26.9 0.1	26.7	26.8	110.9	111.3								58.3 0.4	58.7 0.4	88.9	89.3	0.4	2γ
2	Aug. 7	D	29.9	31.3	23.7 0.1	23.9 0.1	23.5	23.7	94.3	95.1	−35	− 3	−38	−0.6	16 10.0	16 9.4	12 6.9	13 41.2 0.4	13 42.0 0.4	100.5	99.2	−1.3	1.3 W
		H	31.2	31.7	24.1 0.1	24.8 0.1	23.9	24.6	91.9	94.6								38.8 0.4	41.5 0.4	88.2	92.0	3.8	19γ
		Z	31.1	31.2	24.2 0.1	24.7 0.1	24.2	24.7	93.4	95.3								40.3 0.4	42.2 0.4	90.0	91.0	1.0	5γ
3	Dez. 21	D	29.2	29.6	20.7 0.1	21.6 0.2	20.5	21.4	84.2	88.0	+ 6	− 8	− 2	0.0	0 10.0	0 10.0	20 7.5	21 31.7 0.4	21 35.5 0.8	108.8	103.0	−5.8	5.8 W
		H	28.7	29.2	20.3 0.1	21.2 0.1	20.1	21.0	84.0	87.8								31.5 0.4	35.3 0.4	86.8	95.8	9.0	45γ
		Z	29.0	29.2	20.9 0.1	21.0 0.2	20.8	20.9	86.1	86.5								33.6 0.4	34.0 0.8	81.7	81.2	−0.5	−3γ
4	1907 Feb. 9	D	31.4	32.1	2.9 0.1	3.1 0.1	2.6	2.8	10.0	10.7	+ 4	+ 3	+ 7	0.1	18 10.0	18 10.1	14 7.6	14 17.6 0.4	14 18.3 0.4	106.0	109.5	3.5	3.5 E
		H	31.6	31.8	1.8 0.1	2.1 0.1	1.7	2.0	6.4	7.6								14.0 0.4	15.2 0.4	73.7	80.0	6.3	32γ
		Z	31.2	31.4	2.9 0.1	3.2 0.2	2.8	3.1	10.8	11.9								18.4 0.4	19.5 0.8	88.6	88.8	0.2	1γ
5	Juli 10	D	31.1	31.7	4.4 0.1	4.6 0.1	4.1	4.3	15.8	16.6	− 8	+ 6	− 2	0.0	18 10.0	18 10.0	14 7.5	14 23.3 0.4	14 24.1 0.4	104.2	102.0	−2.2	2.2 W
		H	31.2	31.4	4.4 0.1	4.6 0.1	4.1	4.3	15.8	16.6								23.3 0.4	24.1 0.4	85.3	87.0	1.7	9γ
		Z	31.1	31.2	4.1 0.1	4.5 0.1	4.4	4.5	17.0	17.4								24.5 0.4	24.9 0.4	88.2	88.7	0.5	3γ
6	Okt. 13	D	29.5	29.8	23.8 0.2	24.0 0.2	23.7	23.9	96.4	97.2	+ 9	− 2	+ 7	0.1	10 10.0	10 10.1	6 7.6	7 44.0 0.8	7 44.8 0.8	107.0	108.0	1.0	1.0 E
		H	29.5	29.8	24.2 0.2	24.4 0.2	24.1	24.3	98.0	98.8								45.6 0.8	46.4 0.8	74.9	77.0	2.1	10γ
		Z	29.5	29.8	?	?												?	?	?	?	?	?
7	1908 März 26	D	30.4	30.6	24.6 0.1	24.7 0.1	24.5	24.6	96.7	97.1	−12	+ 1	−11	−0.2	20 10.0	20 9.8	16 7.3	17 44.0 0.4	17 44.4 0.4	119.7	118.5	−1.2	1.2 W
		H	30.3	30.5	24.4 0.1	24.8 0.1	24.3	24.7	96.2	97.8								43.5 0.4	45.1 0.4	80.1	91.6	11.5	58γ
		Z	30.4	30.8	24.6 0.2	?	24.4	?	96.3	?								43.6 0.8	?	?	?	?	?
8	Aug. 19	D	30.6	31.2	2.0 0.1	2.8 0.1	1.7	2.5	6.7	9.8	−11	+13	+ 2	0.0	4 10.0	4 10.0	0 7.5	0 14.2 0.4	0 17.3 0.4	111.0	104.8	−6.2	6.2 W
		H	31.0	31.5	2.0 0.1	2.2 0.1	1.8	2.0	7.0	7.7								14.5 0.4	15.2 0.4	74.8	76.8	2.0	10γ
		Z	30.9	31.1	1.9 0.1	2.0 0.1	1.8	1.9	7.0	7.4								14.5 0.4	14.9 0.4	88.1	88.3	0.2	1γ
	9 und 10. Die Uhr des Magnetographen stand.																						
11	Sept. 28	D	29.5	30.0	8.5 0.2	9.2 0.2	8.3	9.0	33.8	36.6	−21	− 1	−22	−0.4	12 10.0	12 9.6	8 7.1	8 40.9 0.8	8 43.7 0.8	107.4	108.3	0.9	0.9 E
		H	29.6	29.8	8.9 0.2	8.9 0.2	8.8	8.8	35.7	35.7								42.8 0.8	42.8 0.8	69.4	68.3	−1.1	− 6γ
		Z	29.2	29.4	9.0 0.1	9.2 0.1	8.9	9.1	36.6	37.4								43.7 0.4	44.5 0.4	87.2	86.7	−0.5	− 3γ
12	Sept. 29	D	30.6	31.2	22.2 0.2	22.3 0.1	21.9	22.0	85.9	86.3	−25	+ 1	−24	−0.4	4 10.0	4 9.6	0 7.1	1 33.0 0.8	1 33.4 0.4	113.8	117.2	3.4	3.4 E
		H	31.3	31.5	22.2 0.2	22.3 0.0	22.1	22.2	84.7	85.1								31.8 0.8	32.2 0.0	71.0	78.0	7.0	35γ
		Z	30.8	31.0	21.9 0.1	22.0 0.1	21.8	21.9	85.0	85.3								32.1 0.4	32.4 0.4	84.4	84.0	−0.4	− 3γ
13	1909 Mai 14	D	29.9	30.5	12.8 0.2	13.1 0.1	12.5	12.8	50.2	51.3	− 5	+ 9	−14	−0.2	8 10.0	8 9.8	4 7.3	4 57.5 0.8	4 58.6 0.4	81.3	78.0	−3.3	3.3 W
		H	30.9	31.0	12.7 0.2	12.9 0.2	12.7	12.9	49.3	50.1								56.6 0.8	57.4 0.8	67.0	70.0	3.0	15γ
		Z	30.2	30.8	12.5 0.2	12.6 0.2	12.2	12.3	48.5	48.9								55.8 0.8	56.2 0.8	82.5	82.8	0.3	1γ
14	Sept. 25	D	29.5	30.2	7.8 0.3	7.9 0.3	7.5	7.6	30.5	30.9	− 4	+ 6	+ 2	0.0	12 10.0	12 10.0	8 7.5	8 39.0 1.2	8 38.4 1.2	77.5	76.5	1.0	1.0 E
		H	29.5	30.0	7.9 0.3	8.0 0.3	7.7	7.8	31.3	31.7								38.8 1.2	39.2 1.2	64.6	65.3	1.0	5γ
		Z	29.3	29.5	8.0 0.2	8.4 0.2	7.9	8.3	32.4	34.0								39.9 0.8	41.5 0.8	86.5	86.2	−0.3	1γ
15	Sept. 25	D	30.4	?	23.6 0.2	24.2 0.2	23.6	24.2	93.2	95.5	− 4	+ 6	+ 2	0.0	14 10.0	14 10.0	10 7.5	11 40.7 0.8	11 43.0 0.8	77.0	115.0	?38.0	?38.0 E
		H	30.1	?	23.2 0.2	23.7 0.3	23.2	23.7	92.5	94.5								40.0 0.8	42.0 1.2	69.0	72.4	3.4	17γ
		Z	30.4	?	23.6 0.2	23.7 0.2	23.5	23.6	92.8	93.2								40.3 0.8	40.7 0.8	87.8	86.0	−1.8	− 9γ

6. Corrigirte Länge des Curvenstücks bis zum Umkehrpunkt:

$$d - \frac{(b-a)}{2} = f = 12.8 \text{ mm.}$$

7. Reduction der Länge e auf Zeitmass:

$$\frac{\left[c - \frac{(b-a)}{2}\right]}{a} .120 = g = 50.2 \text{ min.}$$

8. Reduction der Länge f auf Zeitmass:

$$\frac{\left[d - \frac{(b-a)}{2}\right]}{a} .120 = h = 51.3 \text{ min.}$$

9. Bekannte Correction der Magnetographenuhr gegen die Normaluhr: $u = -5$ sec.

10. Bekannte Correction der Normaluhr: $u_1 = -9$ sec.

11. Correction der Magnetographenuhr auf richtige mittl. Zeit.

$$u + u_1 = -5 - 9 = -14 \text{ sec.} = -0.2 \text{ min.}$$

12. Mittlere Ekaterinburger Zeit des Anfangspunkts des Stücks der Normallinie, uncorrigirt: $U = 8^h\ 10.0^m$.

13. Ditto corrigirt: $U + u + u_1 = 8^h\ 10.0^m - 0.2^m = 8^h\ 9.8^m$.

14. Reduction der Zeit des Anfangspunkts A auf mittlere Greenwicher Zeit, bei $z = 4^h\ 2.5^m$.

$$U + u + u_1 - z = 8^h\ 9.8^m - 4^h\ 2.5^m = 4^h\ 7.3^m.$$

15. Zeit des Anfangspunkts der Störung

$$= U + u + u_1 - z + g = x = 4^h\ 7.3^m + 50.2^m = 4^h\ 57.5^m \pm 0.8^m.$$

16. Zeit des Umkehrpunkts der Störung

$$= U + u + u_1 - z + h = y = 4^h\ 7.3^m + 51.3^m = 4^h\ 58.6^m \pm 0.4^m.$$

17. Ordinate des Anfangspunkts der Störung:

$$GE = m = 81.3 \text{ mm.}$$

18. Ordinate des Umkehrpunkts der Störung:

$$HF = n = 78.0 \text{ mm.}$$

19. Grösse und Richtung des Störungtheils:

$$n - m = -3.3 \text{ mm.}$$

20. Ditto in absolutem Mass: $n - m = 3.'3\ W$.

Hierzu möchte ich noch bemerken, dass bei c und d noch eine Schätzung des Längenfehlers in mm beigefügt ist, die je nach der Dicke der Curve und ihrer mehr oder weniger scharfen Umbiegung, d. h. also des besser oder schlechter zu erkennenden Eintritts des Anfangs der Störung und des ersten Umkehrpunkts variirt. Im Endresultat für x und y sind diese Fehler, reducirt auf Zeit (Zehntel Secunden), beigeschrieben. Bezüglich der Richtung und Grösse der Störung zwischen ihrem Anfang und dem ersten Umkehrpunkte ist zu bemerken, dass einer Zunahme der Ordinaten bei der Declination eine Bewegung des Nordpols des Magneten nach E entspricht, und dass bei H und Z einer Zunahme der Ordinaten auch eine Zunahme der Intensität entspricht.

Um eine Vorstellung der Empfindlichkeit unserer Magnetometer des Magnetographen zu geben, füge ich hier noch die 3 Formeln hinzu, welche im Jahre 1910 verwendet wurden, für die früheren Jahre galten dieselben Formeln, nur waren die Constanten

um geringe Beträge verschieden. Näheres ist in den Jahresberichten des Observatoriums zu finden.

$$d = D_o + (n - n_o)\ (1').$$
$$h = H_o + \{(n - n_o) + 0.832\ (t - 20°.0)\}\ 0.000505.$$
$$z = Z_o + \{(n - n_o) + 0.066\ (t - 20°.0)\}\ 0.000493.$$

DR. P. MÜLLER, *Vicedirector.*

TABLE II. *Eintrittszeiten magnetischer Störungen und ihrer ersten Umkehrpunkte sowie Grösse und Richtung der Störung zwischen diesen Punkten nach mittl. Greenwicher Zeit, beobachtet im Observatorium in Ekaterinburg.*

No.	Datum	El.	Eintrittszeiten		Umkehrpunkte		Richtung und Grösse
			h m	m	h m	m	
1	1906 Juli 29	D	19 58.0	± 0.4	19 58.5	± 0.4	4′.2 W
		H	56.7	0.8	59.2	0.4	40γ
		Z	58.3	0.4	58.7	0.4	2γ
2	Aug. 7	D	13 41.2	0.4	13 42.0	0.4	1′.3 W
		H	38.8	0.4	41.5	0.4	19γ
		Z	40.3	0.4	42.2	0.4	5γ
3	Dec. 21	D	21 31.7	0.4	21 35.5	0.8	5′.8 W
		H	31.5	0.4	35 3	0.4	45γ
		Z	33.6	0.4	34.0	0.8	—3γ
4	1907 Feb. 9	D	14 17.6	0.4	14 18.3	0.4	3′.5 E
		H	14.0	0.4	15.2	0.4	32γ
		Z	18.4	0.4	19.5	0.8	1γ
5	Juli 10	D	14 23.3	0.4	14 24.1	0.4	2′.2 W
		H	23.3	0.4	24.1	0.4	9γ
		Z	24.5	0.4	24.9	0.4	3γ
6	Okt. 13	D	7 44.0	0.8	7 44.8	0.8	1′.0 E
		H	45.6	0.8	46.4	0.8	10γ
		Z	?		?		?
7	1908 März 26	D	17 44.0	0.4	17 44.4	0.4	1′.2 W
		H	43.5	0.4	45.1	0.4	58γ
		Z	43.6	0.8	?		?
8	Aug. 19	D	0 14.2	0.4	0 17.3	0.4	6′.2 W
		H	14.5	0.4	15.2	0.4	10γ
		Z	14.5	0.4	14.9	0.4	1γ
	9 und 10	Die Uhr des Magnetographen stand.					
11	Sept. 28	D	8 40.9	0.8	8 43.7	0.8	0′.9 E
		H	42.8	0.8	42.8	0.8	—6γ
		Z	43.7	0.4	44.5	0.4	—3γ
12	Sept. 29	D	1 33.0	0.8	1 33.4	0.4	3′.4 E
		H	31.8	0.8	32.2	0.0	35γ
		Z	32.1	0.4	32.4	0.4	—3γ
13	1909 Mai 14	D	4 57.5	0.8	4 58.6	0.4	3′.3 W
		H	56.6	0.8	57.4	0.8	15γ
		Z	55.8	0.8	56.2	0.8	1γ
14	Sept. 25	D	8 38.0	1.2	8 38.4	1.2	1′.0 E
		H	38.8	1.2	39.2	1.2	5γ
		Z	39.9	0.8	41.5	0.8	1γ
15	Sept. 25	D	11 40.7	0.8	11 43.0	0.8	38′.0 E ?
		H	40.0	0.8	42.0	1.2	17γ
		Z	40.3	0.8	40.7	0.8	—9γ

MAGNETISCHES OBSERVATORIUM, POLA, 5. FEB. '11.

Die gewünschten Daten über die magnetischen Störungen kann ich Ihnen wegen dringender amtlicher Arbeiten erst heute zur Verfügung stellen.

Im beiliegenden Verzeichnis wurde an sämtlichen Zeitangaben die Korrektion wegen Uhrfehler, wegen Unterschied der Zeitangaben und Zeitmarken sowie wegen des parallaktischen Fehlers der Registrierblätter angebracht; ihre Genauigkeit kann jedoch—einen gleichmässigen Gang der Betriebsuhr vorausgesetzt,—höchstens auf $\pm$ $1^m.0$ veranschlagt werden; bei *Z* sind die Zeitangaben mit Rücksicht auf die Störungen durch die elektrische Strassenbahn auf $+2^m.0$ unsicher. W. KESSLITZ.

HELWAN MAGNETIC OBSERVATORY, EGYPT, JAN. 30, 1911.

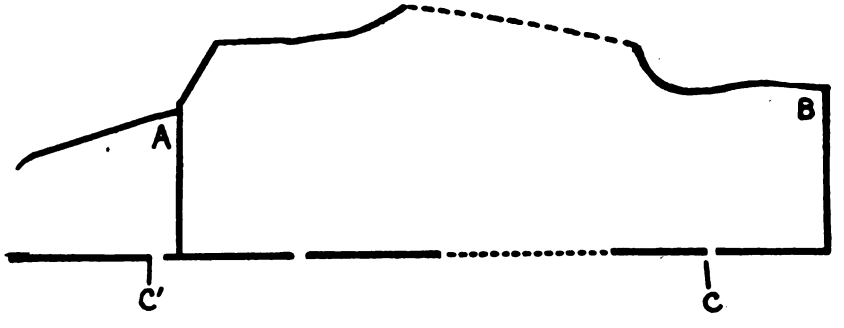
In reply to your letter of December 20, 1910, I have pleasure in sending you the figures you require, with an explanatory note by Mr. Hurst.

B. F. E. KERLING, *Superintendent,*
Khedivial Observatory, Helwan.

Determination of Time on Magnetograms.

The time of the Observatory is determined by transit observations every few days, and the standard clock is one by Riefler. There can be no doubt about the accuracy of the fundamental time, as the longitude of Helwan is known with fair accuracy from a telegraphic determination. The magnetograph clocks were kept within 1 minute of the truth up to 1910, but since then precautions have been taken to keep them right to about ¼ of a minute.

In measuring the time of beginning of a disturbance, the following plan has been adopted in order to eliminate effects due to the curves being of finite thickness. The time scale is 4 minutes to 1 millimetre. The sketch below may be taken as a representation of the commencement of a disturbance.



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Mittlere Greenwicher Zeit des plötzlichen Einsatzes magnetischer Störungen, 1906–1909.

No.	Datum	Element	Einsatz der Störung	Zeit des nächsten Wendepunktes	Ausmass und Charakter der Störung bis zum nächsten Wendepunkte *	Bemerkungen
			h m	h m		
		D	.....	.....	.....	
1	1906 Juli 29	H	19 57.6	19 59.1	+ 32.5γ	
		Z	.....	.....	.....	
		D	13 39.4	13 44.4	+ 1′.2	
2	Aug. 7	H	13 36.0	13 42.0	+ 15.0γ	
		Z	.....	.....	.....	
		D	.....	.....	.....	
3	Dec. 21	H	21 28.6	21 32.6	+ 45.0γ	
		Z	.....	.....	.....	
		D	14 13.2	14 14.2	+ 2′.0	
4	1907 Feb. 9	H	14 11.9	14 14.9	+ 20.0γ	
		Z	14 12.0	14 15.0	+ 9.6γ	
		D	14 25.5	14 30.3	+ 2′.6	
5	Juli 10	H	14 25.1	14 29.6	+ 35.0γ	
		Z	.....	.....	.....	
		D	7 42.8	7 43.8	+ 0′.5	Kleine Zacke, hierauf sukzessive Zunahme
6	Okt. 13	H	7 40.3	7 48.3	+ 17.5γ	
		Z	7 40.0	7 41.0	+ 9.6γ	
		D	17 44.3	.....	.....	Spur einer Zacke, dann sukzessive Abnahme.
7	1908 März 26	H	17 39.8	17 51.8	+ 40.7γ	
		Z	.....	.....	.....	
		D	0 17.5	0 20.5	+ 3′.2	
8	Aug. 19	H	0 13.6	0 15.6	+30.5γ	
		Z	0 14.0	0 16.0	— 4.4γ	
9	Sept. 11	Die Störung fällt in die Zeit des Streifenwechsels				
		D	22 1.4	22 19	+ 3′.0	
10	Sept. 11	H	21 58.2	21 59.7	+101.8γ	
		Z	21 58.0	21 59.0	+ 4.4γ	
		D	8 44.1	8 45.1	— 1′.0	Schwache Zacke, dann +
11	Sept. 28	H	8 41.1	8 42.1	+ 5.1γ	Schwache Zacke, dann —
		Z	8 41.0	.....	— 24.0γ	Sukzessive Aenderung
		D	1 34.1	1 35.1	— 1′.5	Schwache Zacke, dann +
12	Sept. 29	H	1 31.1	1 32.6	+ 45.8γ	
		Z	1 31.0	1 32.0	+ 9.6γ	
		D	4 57.9	5 22.9	+ 13′.0	
13	1909 Mai 14	H	4 52.3	5 0.3	+ 61.0γ	
		Z	4 52.0	4 58.0	— 19.2γ	
		D	8 40.0	8 43.0	+ 2′.0	
14	Sept. 25	H	8 37.1	8 41.1	+ 15.3γ	
		Z	.....	.....	.....	
		D	11 42.4	11 42.9	+ 2′.0	dann +
15	Sept. 25	H	11 39.4	11 52.4	—262.1γ	
		Z	11 39.0	11 40.0	— 16.9γ	dann +

* + bedeutet eine Zunahme der *westlichen* Deklination und der Horizontal- oder Vertikalintensität.

STANFORD LIBRARY

The method practically amounts to measuring from A to B, A being the forward edge of the spot of light when the disturbance commenced, and B the forward edge when the light was shut off the record. The time of B is known, and the time scale is known by measuring up the hourly breaks. Perpendiculars are drawn from A and B to the base line. If the base line is slightly curved the lines from A and B are normals to the curve. From these we can find the time represented by C, and hence by C' if we count the intervening hour marks. From C' we get the time corresponding to A. In some cases where the trace AB has been very close to $C'C$ there are hourly breaks on AB, and in these cases the time corresponding to A can be determined directly without reference to CC'. When this has been done, the two values have never differed by more than one minute. I should say then that in general the time of commencement of a disturbance is correct to within 2 minutes. Where there is greater uncertainty than this, I have indicated it by putting a footnote.

The measurements were made by means of a millimetre scale. Westerly declination is considered positive, and "increase" therefore means a westerly motion of the needle.

Jan. 22, 1911. H. E. HURST.

No.	Date	Commencement of disturbance Greenwich mean time			Disturbance effect		
		Decl.	Hor. Int.	Vert. Int.	Decl.	Hor. Int.	Vert. Int.
		h m	h m	h m			
5	1907 July 10	14 24*	14 21	14 22	increase 1.5′ in 4 min.	increase 25 γ in 2 min.	decrease 9 γ in 2 min.
6	Oct. 13	7 45	7 44	7 45†	increase 1′ in 2 min.	increase 25 γ in 2 min.	decrease 12 γ in 4 min.
7	1908 Mar. 26	No well marked beginning	17 42	17 44	.....	increase 35 γ in 5 min.	decrease 12 γ in 3 min.
8	Aug. 19	0 15	0 16	0 15	increase 2′ in 3 min.	increase 29 γ in 3 min.	decrease 12 γ in 3 min.
9	Sept. 11	7 21	7 22†	7 24	very slight	increase 19 γ in 2 min.	decrease 9 γ in 2 min.
10	Sept. 11	21 48*	21 49†	21 49	increase 2.5′ in 2 min.	increase 115 γ in 3 min.	decrease 39γ in 1 min.
11	Sept. 28	Gradual beginning 8 45	8 39*	8 42	increase 4′ in 14 min.	increase 26 γ in 8 min.	decrease 12 γ in 5 min.
12	Sept. 29	1 32	1 33	.....	decrease 1′ in 1 min.	increase 45 γ in 2 min.	.....
13	1909 May 14	4 57	4 54	4 55	increase 4′ in 4 min	increase 72 γ in 6 min.	decrease 24 γ in 5 min.
14	Sept. 25	8 39	8 38	8 39	increase 1′ in 3 min.	increase 26 γ in 4 min.	decrease 9 γ in 3 min.
15	Sept. 25	11 42	11 39	Lost	increase 3′ in 2 min.	increase 86 γ in 1 min.	.....

* The uncertainty of these measurements is of the order 3 minutes.

† Curves broken by hour marks. The times determined directly from hour marks agreed within 1 minute with those determined from the ends of the curves.

COAST AND GEODETIC SURVEY WASHINGTON, D. C., FEB. 20, 1911.

In response to your letter of the 15th inst., I take pleasure in enclosing herewith the information requested in the second paragraph of your circular letter of December 20, 1910.

A plus (+) sign signifies increase of east declination and increase in horizontal and in vertical intensity.

O. H. TITTMANN, *Superintendent.*

TABLE I.—*Deflections of Sudden Beginnings of Magnetic Storms, 1906–'09.*

No.	Date	Mag. El.	Porto Rico	Cheltenham	Baldwin	Sitka	Honolulu	Remarks
		Δ D	— ?	— 1.′7	— 1.′3	+ 2.′7	+1.′0	
		Δ H	+ 22.1γ	—23.5γ	+ 36.9γ	— 12.9γ	+19.4γ	
1	1906 July 29	Δ Z	.....	— 2.5	— 3.4	+ 6.2	+ 3.7	(a)
		Δ X	+ 22.1	—24.3	+ 48.6	— 17.3	+17.7	
		Δ Y	— 0.6 (?)	— 7.7	— 2.7	+ 4.0	+11.6	
		Δ D	+ 0.′4	+ 1.′3	— 1.′5	— 4.′7	+ 0.′3	
		Δ H	+ 3.1γ	+ 8.7γ	+ 6.3γ	+ 12.9γ	+ 8.6γ	
2	Aug. 7	Δ Z	— 2.5	— 1.6	— 2.0	— 0.6	+ 4.4	(a)
		Δ X	+ 3.2	+ 9.4	+ 7.6	+ 21.8	+ 8.1	
		Δ Y	+ 3.3	+ 6.7	— 8.5	— 11.8	+ 3.9	
		Δ D	— 0.′3	— 2.′3	— 2.′2	— 9.′8	— 0.′3	
		Δ H	+ 17.2γ	+10.0γ	+ 50.1γ	+ 27.3γ	+42.3γ	
3	Dec. 21	Δ Z	+ 15.4	+ 2.9	— 3.0	+ 8.7	+ 4.2	(a)
		Δ X	+ 17.1	+11.3	+ 51.7	+ 45.6	+42.1	
		Δ Y	— 2.7	—14.2	— 6.4	— 24.6	+ 4.4	
		Δ D	+ 1.′8	+ 7.′2	— 2.′0	+ 3.′0	— 1.′0	
		Δ H	+ 7.0γ	+23.2γ	+ 18.0γ	+ 23.0±γ	+18.5γ	
4	1907 Feb. 9	Δ Z	— 16.3	— 4.5	+ 3.0	— (?)	+ 5.1	(b)
		Δ X	+ 7.5	+27.1	+ 19.7	+ 16.8±	+19.6	
		Δ Y	+ 15.0	+39.4	— 9.8	+ 25.4±	— 5.4	
		Δ D	+ 0.′4	+ 1.′0	— 0.′2	— 7.′0	+ 0.′6	
		Δ H	+ 8.0γ	+18.0γ	+ 15.8γ	+ 19.1γ	+18.4γ	
5	July 10	Δ Z	+ 7.1	— 4.8	— 2.0	+ 7.9	+ 8.4	(a)
		Δ X	+ 8.1	+18.5	+ 15.8	+ 32.4	+17.4	
		Δ Y	+ 3.2	+ 4.1	+ 1.0	— 17.8	+ 8.0	
		Δ D	+ 0.′3	— 1.′0	— 1.′3	— 3.′0	— 0.′3	
		Δ H	+ 13.8γ	+17.7γ	+ 25.9γ	+ 16.5γ	+14.1γ	
6	Oct. 13	Δ Z	+ 6.1	+ 1.9	indefinite	+ 4.7	+ 4.8	(a)
		Δ X	+ 13.9	+17.0	+ 26.8	+ 21.1	+14.3	
		Δ Y	+ 2.1	— 7.5	— 4.3	— 3.4	— 0.2	
		Δ D	— 1.′0	— 0.′7	+ 2.′0	.....	+ 1.′4	
		Δ H	+ 12.0γ	—23.7γ	+ 15.8γ	.....	+15.1γ	
7	1908 Mar. 26	Δ Z	+ 11.0	— 5.4	— 11.2	.....	+ 8.4	(b)
		Δ X	+ 11.9	—24.0	+ 13.7	....	+14.7	
		Δ Y	— 9.0	— 1.7	+ 14.8	.....	+ 3.7	
		Δ D	+ 0.′6	+ 3.′6	— 0.′4	— 3.′0	— 1.′0	
		Δ H	+ 13.9γ	+49.6γ	+ 47.2γ	+ 55.7γ	+18.6γ	
8	Aug. 19	Δ Z	+ 7.1	— 1.6	+ 7.6	+ 5.1	+ 5.3	(a)
		Δ X	+ 14.1	+51.4	+ 47.1	+ 55.0	+19.4	
		Δ Y	+ 4.7	+16.0	+ 4.5	+ 16.3	— 5.4	

TABLE I.—*Continued.*

No.	Date	Mag. El.	Porto Rico	Cheltenham	Baldwin	Sitka	Honolulu	Remarks
		Δ D	— 0.′5	— 2.′7	— 1.′7	— 3.′0	+ 0.′2	
		Δ H	+ 4.9γ	+23.7γ	+ 26.0γ	+ 25.3γ	+19.0γ	
9	Sept. 11	Δ Z	+ 6.2	+ 1.2	— 1.0	+ 3.7	+ 6.2	(a)
		Δ X	+ 4.7	+22.1	+ 27.3	+ 32.1	+18.4	
		Δ Y	— 4.5	—17.9	— 6.7	+ 3.0	+ 4.8	
		Δ D	+ 1.′7	+10.3	+ 7.′0	+ 7.′5(?)	+ 1.′5	
		Δ H	+ 16.5γ	+15.5γ	+ 6.8γ	+105.5γ	+21.7γ	
10	1908 Sept. 11	Δ Z	+ 5.7	+ 6.0	+ 10.6	+ 20.3(?)	+11.2	(b)
		Δ X	+ 17.0	+21.1	+ 0.1	+ 74.1	+19.3	
		Δ Y	+ 14.0	+44.5	+ 44.7	+ 82.3	+16.1	
		Δ D	— 0.′8	— 2.′0	— 1.′8	— 1.′0	— 0.′2	
		Δ H	+ 13.5γ (?)	+25.2γ	+ 31.1γ	+ 37.2γ	+22.0γ	
11	Sept. 28	Δ Z	+ 14.7 (?)	+ 0.9	.....	+ 3.8	+ 6.4	(a)
		Δ X	+ 13.3 (?)	+24.0	+ 32.5	+ 34.5	+22.0	
		Δ Y	— 7.4 (?)	—13.9	— 6.6	+ 14.8	+ 1.9	
		Δ D	— 0.′7	+ 2.′6	— 4.′0	Deflection	— 0.′7	
		Δ H	+ 26.1γ (?)	+74.2γ	+ 41.0γ	Observations	+30.2γ	
12	Sept. 29	Δ Z	+ 24.3 (?)	— 4.3	— 5.0	Interrupted	+13.4	(b)
		Δ X	+ 25.9 (?)	+75.3	+ 44.3	the Record.	+30.7	
		Δ Y	— 6.9 (?)	+ 7.9	— 18.8		— 1.0	
		Δ D	+ 1.′0	+ 4.′9	— 1.′4	+ 9.′3	+ 4.′3	
		Δ H	+ 72.0γ	+97.5γ	+ 97.8γ	+113.0γ (?)	+55.0γ	
13	1909 May 14	Δ Z	+ 28.0	— 5.5	— 2.4	+ 34.5	+16.9	(a)
		Δ X	+ 72.3	+99.8	+ 98.0	+ 76.4 (?)	+48.3	
		Δ Y	+ 5.7	+18.7	+ 5.9	+ 93.3 (?)	+45.0	
		Δ D	+ 1.′1	— 3.′8	— 2.′8	+ 3.′2	+ 0.′7	
		Δ H	+ 16.8γ	+20.6γ	+ 25.5γ	+ 32.1γ	+14.7γ	
14	Sept. 25	Δ Z	+ 7.7	— 1.0	— 1.5	— 3.3	+ 5.7	(a)
		Δ X	+ 17.2	+18.4	+ 27.8	+ 20.4	+13.5	
		Δ Y	+ 8.7	—23.9	— 13.6	+ 28.7	+ 8.3	
		Δ D	+ 25.′0	.....	— 25.′0	— 7.′3	+ 1.′1	
		Δ H	+114.0 + γ	— (?)	—<150.0γ c	+ 64.2	<+95.0γ c	
15	Sept. 25	Δ Z	+ 56.3	—14.7γ (?)	— 38.9	—off sheet	+65.0 ±	(b)
		Δ X	+121.9 ±	.....	—<124.8	+ 72.1	<+92.2	
		Δ Y	+206.4 ±	.....	—<133.4	+ 3.7	<+24.8	
			h m	h m	h m	h m	h m	
		D	8 28.1	8 30.1	8 27.3	8 30.4	8 33.7	
		H	27.5	31.9	29.7	28.4	34.0	
		Z	29.6	.....	31.8	35.5	.....	
		Δ D	— 0.′5	— 1.′4	— 1.′2	— 1.′7	— 0.′5	c =
14	Sept. 25	Δ H	+ 2.1γ	+ 3.9γ	+ 9.1γ	+10.9γ	+ 2.5γ	off
a*		Δ Z	+ 4.2	.....	— 1.2	+ 3.0	.....	sheet.
		Δ X	+ 2.0	+ 3.1	+10.0	+13.3	+ 3.2	
		Δ Y	— 4.3	— 8.6	— 8.8	— 1.1	— 3.8	

* The beginnings of this perturbation were in general not very sudden, and not well adapted for accurate time scaling.

TABLE II. *Approximate time interval between sudden beginning and first turning point of magnetic disturbances, 1906–1909.*

No.	Date	Mag. El.	Porto Rico	Cheltenham	Baldwin	Sitka	Honolulu	Remarks
			m	m	m	m	m	
		D	...	1.2	0.8	0.8	3.0	
1	1906 July 29	H	0.9	0.5	3.0	2.0	4.5	(a)
		Z	...	1.0	0.8	0.8	1.5	
		D	2.1	1.2	2.1	3.9	2.4	
2	Aug. 7	H	2.1	1.5	1.2	1.2	3.0	(a)
		Z	2.4	1.8	1.8	1.5	3.0	
		D	0.8	1.5	1.0	0.8	0.8	
3	Dec. 21	H	1.5	0.6	1.8	1.2	2.0	(a)
		Z	1.8	1.0	1.5	1.0	2.0	
		D	3.6	3.8	0.8	0.8	2.1	
4	1907 Feb. 9	H	0.8	0.8	0.8	0.8	1.8	(b)
		Z	3.0	1.2	2.2	(?)	2.0	
		D	0.6	0.8	1.2	2.0	7.5	
5	July 10	H	0.9	0.8	1.0	1.5	1.8	(a)
		Z	1.2	1.2	0.9	2.1	1.8	
		D	1.5	2.5	3.0	2.4	3.0	
6	Oct. 13	H	4.5	2.4	3.6	3.0	3.0	(a)
		Z	1.8	1.7	...	3.0	2.1	
		D	1.0	1.0	1.5	...	9.0	
7	1908 Mch. 26	H	1.5	0.8	0.6	...	2.1	(b)
		Z	2.0	2.0	7.8	...	2.1	
		D	3.6	4.0	1.2	1.5	3.6	
8	Aug. 19	H	2.4	3.7	4.5	3.6	4.5	(a)
		Z	2.4	1.5	5.1	1.8	3.3	
		D	3.0	3.5	3.3	1.8	3.9	
9	Sept. 11	H	3.6	3.6	3.9	3.6	2.2	(b)
		Z	3.0	1.5	1.8	2.1	3.6	
		D	2.4	1.8	3.3	1.5(?)	0.8	
10	Sept. 11	H	0.9	3.0	2.4	2.4	1.5	(b)
		Z	1.8	0.6	2.4	1.5(?)	0.7	
		D	3.0	2.1	2.1	1.2	1.2	
11	Sept. 28	H	4.5	2.4	3.6	3.3	5.1	(a)
		Z	3.3	1.5	...	2.4	3.6	
		D	1.2	2.0	1.0	...	0.9	
12	Sept. 29	H	1.8	3.0	4.5	...	0.6	(b)
		Z	1.2	2.0	0.8	...	1.5	
		D	3.6	4.5	0.8	1.2	36.0	
13	1909 May 14	H	9.9	9.0	6.0	(?)	9.6	(a)
		Z	8.1	4.5	0.8	18.0	6.0	
		D	3.0	4.5	4.8	3.0	3.9	
14	Sept. 25	H	4.2	3.9	4.5	4.8	3.9	(a)
		Z	4.2	...	4.8	3.6	...	
		D	13.5	3.8	3.0	0.7	1.0	
15	Sept. 25	H	2.5	3.0	3.6	0.6	13.5	(b)
		Z	3.0	3.0	3.0	...	1.5	
		D	2.4	3.0	2.4	2.0	9.0	
14a	Sept. 25	H	1.5	2.0	1.5	1.4	1.0	
	8h 30m G. M. T.	Z	2.4	...	1.8	3.0	...	

BOMBAY MAGNETIC OBSERVATORY, INDIA, FEB. 4, '11.

Herewith the data as desired in your letter of the 20th December 1910. One cm. of ordinate is equal to about 10'.3 in D, 45γ in H., and 90γ in V (Z). The interval of one hour on the Bombay curves is about 14.8 mm. only. The time scale of the tabulator is divided to 5 minutes which is subdivided by the vernier (reading) to 1 minute. The tabulations have been independently measured by two observers and finally the mean of their results has been adopted. I fear the results of the whole, however, can not be depended upon for greater accuracy in time than of 1 minute considering that the turning points themselves can scarcely be determined with absolute certainty.

The sign + means increase of easterly declination, H.F. and V.F. In all cases the sudden jerky movements denote a westerly elongation of the declination needle, an increase in the horizontal force and a decrease in the vertical force. I trust the data would be found sufficient for your requirements.

N. A. F. MOOS, *Director, Bombay and Alibag Observatories.*

BUREAU CENTRAL MÉTÉORLOGIQUE, PARIS, 21 FÉVR. '11.

Conformément à votre lettre du 21 Décembre, j'ai fait parvenir votre circulaire aux stations magnétiques du Val Joyeux, de Nantes (Petit Port), de Perpignan et du Pic du Midi. Il n'est pas fait d'observations magnétiques au Puy-de-Dôme.

Je m'empresse de vous communiquer ci-inclus les réponses qui me sont données par le Val Joyeux et Perpignan;[1] ces dernières sont très incomplètes car les observations y sont rendues très difficiles par le voisinage de tramways électriques. Les courbes étaient cependant utilisables par parties lorsque les départs des voitures étaient peu fréquents. Maintenant que la circulation est devenue beaucoup plus active, il n'y a plus rien à faire et les observations de Perpignan seront définitivement supprimées à la fin de ce mois.

Je n'ai rien reçu encore de Nantes et du Pic du Midi; il est possible que M. Marchand vous expédie directement sa réponse. En

[1] The data for Perpignan are not printed, as they are too few in number, and, furthermore, did not possess the required accuracy, doubtless because of reasons above stated.—L. A. B.

Tabulation of times and ordinates of sudden sharp beginnings of certain magnetic storms at Bombay during the period 1906—1909.

No.	Date	Magnetic Element	Time of beginning G. M. T.	Disturbance effect between the beginning and first sharp turning point	Time interval between the beginning and the first sharp turning point
			h m		m
1	1906 July 29	D	19 56.4	— 0′.4	2.5
		H	19 56.4	+ 26γ	4.0
		V	19 56.2	— 4γ	3.2
2	Aug. 7	D	13 38.4	— 0′.1	2.3
		H	13 38.2	+ 7γ	2.5
		V	13 38.2	not appreciable	2.2
3	Dec. 21	D	21 29.2	— 1′.4	9.7
		H	21 30.2	+ 65γ	9.2
		V	21 28.9	— 12γ	10.0
4	1907 Feb. 9	D	14 12.4	— 0′.2	3.3
		H	14 13.1	+ 19γ	1.8
		V	14 12.9	— 1γ	2.8
5	July 10	D	14 22.2	— 0′.7	4.7
		H	14 22.4	+ 29γ	6.3
		V	14 22.7	— 5γ	4.0
6	Oct. 13	D	7 43.2	— 0′.4	3.7
		H	7 43.9	+ 22γ	6.8
		V	7 43.2	— 4γ	4.5
7	1908 Mar. 26	D	17 40.7	— 0′.6	3.5
		H	17 41.4	+ 32γ	3.8
		V	17 41.2	— 6γ	3.7
8	Aug. 19	D	0 13.7	— 0′.1	3.2
		H	0 13.2	+ 15γ	4.0
		V	0 14.2	— 2γ	2.7
9	Sept. 11	D	7 20.7	— 0′.3	3.7
		H	7 20.7	+ 20γ	3.5
		V	7 21.2	— 3γ	3.5
10	Sept. 11	D	21 46.4	— 2′.4	12.0
		H	21 45.4	+119γ	12.3
		V	21 46.2	— 14γ	11.0
11	Sept. 28	D	8 40.9	— 0′.2	3.0
		H	8 41.4	+ 18γ	6.3
		V	8 41.2	— 2γ	3.0
12	Sept. 29	D	1 30.9	— 0′.3	3.0
		H	1 31.2	+ 23γ	1.5
		V	1 31.7	— 3γ	2.2
13	1909 May 14	D	4 54.4	— 1′.6	9.3
		H	4 53.7	+ 67γ	10.7
		V	4 53.9	— 15γ	8.8
14	Sept. 25	D	8 37.7	— 0′.1	3.7
		H	8 38.0	+ 22γ	4.8
		V	8 37.9	— 2γ	5.0
15	Sept. 25	D	11 41.4	— 3′.1	0.8
		H	11 42.2	+101γ	1.2
		V	11 41.2	— 20γ	2.0

tous cas, aussi bien à Nantes et au Pic du Midi qu'à Perpignan, les observations sont très simplifiées; il n'est pas fait, en particulier, de mesures absolues, sauf de temps en temps à Perpignan. J'ajouterai enfin que la station de Nantes est condamnée à son tour et sera probablement supprimée d'ici un an par suite de la création d'un réseau de tramways électriques dans cette région où, jusqu'ici, on n'employait que la traction mécanique. A. ANGOT,

Directeur du Bureau Central Météorologique de France.

VAL JOYEUX, FRANCE.

Brusque commencement des perturbations magétiques de 1906–1909. L'erreur provenant du dépouillement doit à peine atteindre 0m. 5, mais l'incertitude sur la régularité absolue de la descente du cadre contenant la feuille de papier sensible doit porter l'erreur possible à environ 1m. (Heures en t. m. civil de Greenwich).

No.	Année	Date	D	H	Z	
			h m	h m	h m	
1	1906	29 Juillet	19 51.2 *	19 56.0	19 56.6	(a)
2		7 Août	13 39.2	13 36.9	13 40.3	(a)
3		21 Décembre	21 30.0	21 30.0	21 33.7	(a)
4	1907	9 Février	14 11.4	14 11.4	14 14.1	(b)
5		10 Juillet	14 23.0	14 23.0	14 26.6	(a)
6		13 Octobre	7 39.8	7 38.6	7 42.8	(a)
7	1908	26 Mars	.....	17 38.0	.....	(b)
8		19 Août	0 16.7	0 16.1	0 19.7	(a)
9		11 Sept.	7 20.0	7 20.0	7 24.8	(a)
10		11 Sept.	21 47.1	21 45.9	21 48.9	(b)
11		28 Sept.	8 41.7	8 41.1	8 45.3	(a)
12		29 Sept.	1 33.5	1 33.5	1 35.9	(b)
13	1909	14 Mai	4 57.8	4 56.6	4 61.4	(a)
14		25 Sept. †	8 39.3	8 39.3	.....	(a)
15		25 Sept.	11 41.1	11 41.1	11 42.3	(b)

* Soigneusement vérifié.

† La courbe du 25 Septembre 1909 indique un mouvement brusque et bien net antérieur à celui qui est indiqué au tableau et qui paraît bien correspondre à celui qui a été adopté généralement; ce 2e mouvement est indiqué ci-dessous :

1909 Sept. 25 $8^h\ 29^m.7$ $8^h\ 29^m.7$ $8^h\ 32^m.7$ (a')

Edm. Halley

ON TIME SCALINGS OF MAGNETOGRAMS.[1]

By R. L. Faris.

From some of the recent discussion[2] that has appeared in reference to the accuracy of the time scalings of magnetograms (photomagnetic records) in connection with the study of the non-simultaneity of abruptly beginning magnetic storms it would seem helpful to a clearer understanding of the subject to state specifically the method of time scalings that has obtained in reducing the results of the Coast and Geodetic Survey magnetic observatories.

The five magnetic observatories of the Coast and Geodetic Survey are all equipped with a complete set of Eschenhagen type of variometers[3] (Cheltenham having also an Adie magnetograph) and the photographic recording apparatus is so arranged that a time interval of one hour on the magnetograms is approximately twenty millimeters in length, thus making one millimeter correspond to a three minute time interval. The beginning of each hour is recorded on the base lines of the magnetogram by the light from the fixed mirrors of the variometers being interrupted, for a short interval of time, by small automatic shutters in the recording apparatus. The magnetic traces as well as the base-lines are mechanically interrupted (by the observer) at least once each day, usually about 8 o'clock every morning. The time of this interruption, or break in the curves and base-lines, is recorded. The error of the driving clock of the recording apparatus is then known from these daily comparisons with the standard observatory chronometer, the error of the latter on local mean time is known certainly to one-tenth of a minute of time from observations made for the purpose about once a week or oftener if found necessary. There are five points on each magnetogram of about 24 hours' length, where time comparisons are made with the standard observatory chronometer, all five of which are recorded on the base lines, and three of which are recorded on the magnetic curves themselves, viz: at the beginning of the twenty-four hour record (when the new photo-sheet is put on), usually about 4: 10 p. m., then another time comparison at the 5: 00 p. m. hour break; the third reading is made about 8: 00 a. m. the following morning (when the interruption of the magnetic trace is made as above mentioned); the fourth comparison of the time is made at the 4: 00 p. m. time break, and finally a

[1] Published by permission of the Superintendent of the United States Coast and Geodetic Survey.

[2] See *Nature*, Dec. 8, 1910, p. 170; and Dec. 22, 1910, p. 236.

[3] *Terr. Mag.*, v. 12, pp. 73–76; v. 8, pp. 11–29. Also App. 5, C. & G. S. Report for 1902.

reading of the time is made at the close of the twenty-four hour record when the photographic sheet is removed from the drum of the recording apparatus. As soon as the magnetogram is taken from the recording apparatus it is marked with distance marks (small holes are pricked through from the back of the trace at a known distance apart, by two small metal points fixed in a small wooden beam, like a beam compass), so that on the finished record, after it has been developed and fixed, the correction for shrinkage of the traces can be made if necessary, in scaling the ordinates when making the numerical tabulations.

On all magnetograms it will generally be found that the point of beginning of the photographic trace of the magnetic element (*D*, *H*, or *Z*) does not lie exactly normal to the point of beginning of the corresponding base-line, or if the traces and base-lines are mechanically interrupted (as above mentioned), it will be found that the beginning of the interruption on the trace of the magnetic element is not exactly perpendicular to the beginning of the interruption on its corresponding base-line. This lack of perpendicularity is what is known as the "overlap" or "parallax," and it must be measured and taken into account in ascertaining the time at any desired point on the magnetic traces. The amount of parallax may be, and generally is, different for the three magnetic elements which in the Eschenhagen system are all recorded on the same photographic sheet, or magnetogram. From the foregoing, it will be seen then, that the correction for parallax or overlap can be measured at the beginning of the daily record (about $16^h\ 10^m$, l. m. t.) from the $8^h\ 00^m$ a. m. interruption, and from the end of the day's record (about $16^h\ 05^m$, l. m. t.).

In ascertaining the time corresponding to any desired point on a magnetic trace, the point is projected perpendicularly onto the corresponding base-line (which is also the time line, having the hourly time breaks registered upon it) by means of a large right-angled triangle, one side of which is laid along the base-line and the other right-angled side cutting the desired point on the trace, or else use is made of a magnetogram reading board,[4] the latter being used exclusively for reading the hourly ordinates of the magnetic curves, the maxima and minima, etc. All of the time scalings given in Table I, p. 101, vol. 15, of this Journal were made with the use of a right-angled triangle, the right-angled sides of which were 17.5 cm and 30.4 cm (whole length of base-line is about 48 cm), the longer side being placed along the base line. The triangle was also used in ascertaining the parallax or overlap correction.

In making the time readings just above mentioned, the following was the order of procedure: The point on the magnetic curve was

[4] For description of this reading board see p. 7 "Results of Observations made at the Coast and Geodetic Survey Magnetic Observatory at Cheltenham, Maryland, 1901–04," by *D. L. Hazard*, Wash. Govt. Printing Office, 1909.

first decided upon, and in reading the time of occurrence of any particular feature of a magnetic perturbation as recorded at different observatories it is often more difficult to decide upon the exact correspondences in the curves than it is to read the time after the point on the curve is decided upon. In the matter of identifying the record of the same magnetic impulse at different observatories, the more records one has of different observatories the easier it is to pick out identical phases, or in other words, having several records to compare is an assistance in recognizing the correspondences. Without this aid corresponding perturbations at different stations would often not be so well identified and sometimes overlooked altogether. The point being decided upon it was then projected normally on its corresponding base-line (which is also the time line) with the aid of the triangle. The fractional part of the hour upon which the point fell was then scaled off in millimeters, using a small metal millimeter scale, and then converted into minutes of time. The interval between the hour breaks, corresponding to one hour, was measured each time, and the scaling for the fractional hour was corrected, if necessary, for any variation in the length of the hour interval. The error of the time marking clock (the driving clock of the registering apparatus) on local mean time was then applied. This result was then corrected for parallax or overlap, ascertained as above mentioned, and finally, it was expressed in Greenwich mean time by the application of the difference in longitude between the station and the Greenwich meridian. The base-lines were tested by the long side of the triangle to ascertain if they were straight lines.

As an example of the practical measure of agreement in time scalings from magnetograms, the record of the time of occurrence of the lightning discharge which struck the Cheltenham magnetic observatory on July 12, 1910,[5] has again been taken up and new and independent readings made by Mr. Hazard and myself. The following are the means of the times for all three elements (*D*, *H*, and *Z*) of the time of occurrence of the lightning stroke which produced an abrupt break in the magnetic traces:

h	m		
18	55.0,	l. m. t.	(Faris, September, 1910.)
18	55.3,	l. m. t.	(Hazard, September, 1910.)
18	54.9,	l. m. t.	(Faris, January, 1911.)
18	55.2,	l. m. t.	(Hazard, January, 1911.)
18	55.1,	l. m. t.	(Faris, January, 1911.)
18	55.4,	l. m. t.	(Hazard, January, 1911.)

The last two values above given were read by a method that is independent of the overlap (or parallax) measurement and of any error

[5] See *Terr. Mag.*, v. 15, p. 213.

in projecting the point on the magnetic curve onto the base-line. This method, which was suggested by Mr. Hazard, consists in measuring the interval on the magnetic trace between some mechanical break on it and the desired point, and then taking this same interval on the base-line starting from the same mechanical break; the break in the present case being the beginning of the day's record. The mechanical break on the magnetic curve and on its base-line are of course simultaneous, such for instance as the beginning or ending of the day's record, or the interruption about 8:00 a. m., previously mentioned. In the case of the last two results above given the time as scaled for each of the three elements separately was the same as the mean result given.

It will be noted that in the above mentioned scalings those by the same method in September by Faris are $0.^{m}1$ higher than the January reading, and the same is true of the two readings by Hazard, his readings in both cases being $0.^{m}3$ higher than Faris; this is also true of the last two readings given (by the direct method). This persistent difference of $0.^{m}3$ in the scalings by two different persons would seem to indicate the possibility of the existence of "personal equation" in making magnetogram time scalings.

COAST AND GEODETIC SURVEY,
Washington, D. C., January 25, 1911.

THE PHYSICAL THEORY OF THE EARTH'S MAGNETIC AND ELECTRIC PHENOMENA.—No. IV.

By L. A. Bauer.

On the Origin of the Earth's Magnetism.

42. In the previous number, the hypothesis was set up (§29) that "the Earth is chiefly an electromagnet, the magnetizing currents being outside and consisting of negative electric currents circulating overhead in the same general direction as that of the Earth's rotation, namely, from west to east." The external currents are revealed by the harmonic analysis of the magnetic elements observed on the Earth's surface (§37). Starting with these currents, it was found that, *qualitatively*, the Earth, if paramagnetic, would be magnetized by them in the general direction in which it is actually found to be and that *quantitatively*, the magnetization of our planet can be accounted for, if its average magnetic permeability is on the order of 135 for a magnetizing force of about 0.0024 C. G. S. This value while high was shown not to be impossible and, in fact, it is not as great as has been thought necessary in order to account for the Earth's magnetism electromagnetically; as these researches progress it is quite likely that the value will receive some modification.

It was furthermore shown (§29-33) that the hypothesis as above stated was in full harmony with the theorem underlying the Gaussian analysis. This theorem as given by Schuster[1] is: "If the magnetic forces at all points of the surface of a sphere can be represented in terms of a potential which is expressed as a series of spherical harmonics proceeding by negative powers of the radius vector, then there are no magnets or electric currents outside the sphere." The application of this principle has revealed the fact that only to the extent of about 5 per cent do the existing magnetic observations disclose effects referable to systems above the Earth's surface. While this is doubtless conclusive proof that the "magnets or electric currents" which cause the effects observed on the surface have their seat almost wholly within the Earth, it does not exclude the possibility that the internal magnetism has been excited electromagnetically by outside currents. The whole question depends upon the strength of the external currents and the Earth's magnetic

[1] *Nature*, London, Apr. 20, 1905 (578-9).

permeability. The direct magnetic effect of the external currents as felt at points on the surface may be very small, though the indirect effect due to their magnetizing a highly permeable body may, in comparison, be very great.

It should, therefore, be borne in mind that while the results of the Gaussian analysis may be accepted as conclusive respecting the seat or location of the magnets and electric currents, which together constitute what is known as the "Earth's permanent magnetic field", nothing whatever is determined as to the origin or cause of the magnetizations and of the currents. Later quantitative tests, to be applied as soon as certain required data are available, may prove the untenability of our hypothesis, but at present there are no definite facts to make the supposition that the Earth is chiefly an electromagnet due to outside electric currents, unworthy of serious consideration.

43. Though it may be argued that by ascribing the Earth's magnetism to an outside electric system, we are simply referring one cause to another, it can not be said that we are attempting to remove one great difficulty by substituting another equally as great. While we are not ready as yet to account fully for the origin of the external currents, it suffices for the present purposes to know that the upper atmospheric strata possess the requisite electric conductivity to make their existence possible. Besides the evidence already furnished by the mathematical analyses of the permanent and of the disturbance fields, let us recall the researches of Schuster, who first proved that the diurnal variation of the Earth's magnetism is primarily due to outside electric currents, though also in part to inside ones.[2] See also the results of my analysis of the secular variation of the Earth's magnetism given in PD No. V (*Terr. Mag.*, v. 9, p. 186), which proved the existence of an outside system of forces in addition to an internal one.

In brief, we must have outside currents to account for many of the most striking of the Earth's magnetic phenomena. Their existence granted and given sufficient magnetic permeability and electric conductivity, the internal magnetizations and electric currents can be deduced. Furthermore, there are abundant, physically demonstrable, causes for variations in the external currents; any change in the electric conductivity of the atmospheric strata due to some

[2] *Phil. Trans. R. S. London*, v. 180 (1889), A, 467-518, and v. 208 (1908), A, 163-204.

ionizing effect, for example, will produce changes. The temporary abstraction of ordinary solar radiation from a portion of the atmosphere is accompanied by magnetic effects (solar-diurnal variation; total-solar-eclipse variation). If, then, we start with outside electric currents as the prime origin of most of the facts revealed by magnetic needles on our planet, let it be remembered that the *one* cause includes within itself, at the same time, the possibility of permanent as well as variation effects. The inverse of the problem, assuming internal magnetism or currents to exist, and deducing inductively or electrodynamically outside currents, meeting all requirements will be found to present greater difficulties.

44. Let it be recalled, also, that all attempts to account for the Earth's magnetism by causes contained within the Earth itself, though made by brilliant minds, have met with failure or have not been accepted. Nevertheless the result of the analysis introduced by Gauss in his celebrated and oft-quoted memoir, published in 1839 and entitled "Allgemeine Theorie des Erdmagnetismus" (General Theory of the Earth's Magnetism), has had such overpowering influence that it is still generally believed necessary to seek for an *internal* cause of terrestrial magnetism.

It was perhaps unfortunate that Gauss used the words "General Theory" in the title of his paper. Had he said "The Potential Theory of the Earth's Magnetism", or "The Earth's Magnetic Potential", the actual subject matter would have been more cogently expressed and some confusion would have been prevented. Examining the memoir carefully, it is seen that it does not really contain any theory, in the modern sense of that word, of terrestrial magnetism; it does not attempt to account for the Earth's magnetism, but instead shows in a very elegant manner how the principles of the potential theory are to be applied to the mathematical representation of such a complex subject as the distribution of the terrestrial magnetic forces. Strictly speaking, then, the Gaussian potential formula of the Earth's magnetism is merely an empirical expression, established in accordance with the best mathematical principles and based on no presupposed distribution of magnets or currents within or outside the Earth; as said, it simply aims to represent in the most approved manner the facts observed.

Gauss's contribution was a great improvement upon all previous similar attempts. It taught that the observed magnetic forces can be almost wholly referred to a potential. It furthermore showed

for the first time how to separate effects due to internal magnetic or electric systems from those due to outside ones. But Gauss himself made no attempt to interpret physically any of the terms of his total potential, not even of the first harmonic which since his time has been found to represent a simple uniform magnetization about a diameter inclined to the axis of rotation.

45. Ampère had set up the hypothesis that the Earth was an electromagnet, but, coupled with the result from the Gaussian analysis, the accepted conclusion has been that if the Earth be an electromagnet, then the magnetizing currents must be *below* the surface. It is against the necessity of locating the currents inside the Earth that we are contending. The available Earth current data, moreover, have not yet definitely revealed the kind of internal electric current system required to produce the Earth's magnetism.

46. A significant passage in connection with the problem of finding sufficient causes for internal magnetizations and currents occurs in Faraday's "Experimental Researches in Electricity", vol. III, sec. 2848, which it will be of interest to give in full:

> The Earth presents us with a spheroidal body, which, consisting of both paramagnetic and diamagnetic substances, disposed with much irregularity as regards its large divisions of earth and ocean, are also equally irregularly disposed and intermingled in its smaller portions. Nevertheless it is, on the whole, a magnet, and, as far as we at this moment are concerned, an original source of that power. And though we can not conceive at present that all the particles of the Earth contribute, as sources, to its magnetism, inasmuch as many of them are diamagnetic, and many non-conductors of electric currents, yet it is difficult to say that any large portion is not concerned in the production of the force; hereafter it may be necessary, perhaps, to consider certain parts as mere conductors, *i. e.*, as parts merely permeated by the lines of force, originating elsewhere, but for the present the whole may be assumed, according to the theory of Gauss, as a mighty compound magnet.

Attention is called here chiefly to the latter part of this passage: *"hereafter it may be necessary, perhaps, to consider certain parts as mere conductors, i. e., as parts merely permeated by the lines of force, originating elsewhere."*

47. Lord Kelvin in his much-discussed Presidential Address before the Royal Society, in 1892,[3] says:

> Considering probabilities and possibilities as to the history of the Earth from its beginning to the present time, I find it unimaginable but that ter-

[3] London, *Proc. R. Soc.* v. 52, 1893, 304-308.

restrial magnetism is due to the greatness and the rotation of the Earth. If it is true that terrestrial magnetism is a necessary consequence of the magnitude and the rotation of the Earth, other bodies comparable in these qualities with the Earth, and comparable also with the Earth in respect to material and temperature, such as Venus and Mars, must be magnets comparable in strength with the terrestrial magnet, and they must have poles similar to the Earth's north and south poles on the north and south sides of their equators, because their directions of rotation, as seen from the north side of the ecliptic, are the same as that of the Earth. It seems probable, also, that the Sun, because of its great mass and its rotation in the same direction as the Earth's rotation, is a magnet with polarities on the north and south sides of its equator, similar to the terrestrial northern and southern magnetic polarities. . . . . .

We are certainly far from having any reasonable explanation of any of the magnetic phenomena of the Earth; whether the fact that the Earth is a magnet; that its magnetism changes vastly, as it does from century to century; that it has somewhat regular and periodic annual, solar diurnal, lunar diurnal, and sidereal diurnal variations; and (as marvelous as the secular variation) that it is subject to magnetic storms. The more marvelous, and, for the present inexplicable, all these subjects are, the more exciting becomes the pursuit of investigations which must, sooner or later, reward those who persevere in the work. We have at present two good and sure connexions between magnetic storms and other phenomena: the aurora above, and the earth currents below, are certainly in full working sympathy with magnetic storms.

48. Of present-day magneticians I have thus far been able to find only one, August Schmidt, of Stuttgart, Germany (not to be confounded with Adolf Schmidt, of Potsdam), who has questioned the general conclusion drawn from the Gaussian analysis. In a suggestive paper[4] the following significant passages occur; I have italicized the sentences to which special attention is called:

Wenn ausser den unregelmässig in der Erdkruste zerstreuten, häufig regellos gerichteten permanent magnetischen Gesteinen die Erde keinen anderen permanenten Magnetismus besitzt, so muss sie temporär magnetisch sein. Die Ursache des Erdmagnetismus sind dann entweder innere Ströme, welche ein magnetisches Feld erzeugen, oder sind es ausser der Erde liegende Ursachen. Für die directe Bildung innerer Ströme lässt sich aus der Axendrehung der Erde kein einleuchtender Grund ableiten, wohl aber für die Bildung äusserer Ströme. Nicht bloss die Passatströmung kann vielleicht einen solchen Anlass bieten, sondern die ganze Beziehung der rotirenden Erdatmosphäre zu dem sie durchdringenden und umgebenden Aether.

[4] Erdmagnetismus und Erdgestalt. Beitr. Geophysik, Leipzig, v. 2, 1893 (197–210). See also the same author's papers: Michael Faraday's Ansicht vom Erdmagnetismus, Besondere Beilage, Staats-Anzeigers für Württemberg, No. 1 and 2, March 29, 1895 (21–29); Ueber den Bestand des Saturn rings, Jahreshefte d. Vereins für vaterl. Naturkunde in Württ., 1894, (18–34).

Nach Lord Kelvin's Bericht ist es durch die Bearbeitung der Statistik der erdmagnetischen Störungen höchst wahrscheinlich geworden, dass dieselben ihre Ursache ausserhalb der Erde haben. Die Uebereinstimmung der Periodicität dieser Störungen mit der Periode der Sonnenflecken ist ebenso unleugbar wie der Zusammenhang dieser Störungen mit den Polarlichtern. *Sollte nicht die ganze Ursache des Erdmagnetismus, das ganze primum movens desselben ausserhalb liegen?* Alle die periodischen Jahres-, Sonnentags-, Mondtags- und Sterntagsschwankungen des Erdmagnetismus, seine Veränderung mit der Luftfeuchtigkeit, mit den Gewittern, sind Anzeichen dafür, dass seine Ursache eine theils kosmische, theils atmosphärische sei.

Es ist das unsterbliche Verdienst von Gauss, gezeigt zu haben, dass ostwestliche Ströme ausserhalb der Erde die Ursache des Erdmagnetismus nicht sind, aber eine moderne Anschauungsweise gestattet uns in westöstlichen Strömen ausserhalb der Erde die Ursache zu erkennen. Hopkinson hat eine ganz neue Betrachtungsweise in die Theorie der magnetischen Kraftlinien eingeführt, er stellt sie in Parallele mit den elektrischen Strömen, denn auch die Kraftlinien sind wie jene in sich zurücklaufend, er wendet mit Erfolg auf ihren Verlauf das Ohm'sche Gesetz über Stromstärke, Widerstand und "magnetomotorische" Kraft an. Wir sind dieser Betrachtungsweise entsprechend gleich berechtigt, die magnetomotorische Kraft in dem Verlaufe der Kraftlinien ausserhalb oder innerhalb der Erde zu suchen. *Wenn nur die magnetische Leitungsfähigkeit der Erdmasse sehr gross ist, so wird sie die Kraftlinien aus den weitesten Entfernungen gegen sich herziehen, durch sich hindurchleiten. Diese Leitungsfähigkeit ist eine Function, die mit dem Magnetisirungsfactor k eng zusammenhängt und mit demselben gross oder klein ist. Daher ist es für die Möglichkeit der Erklärung des Zusammenhangs des Erdmagnetismus mit atmosphärischen und kosmischen Erscheinungen vom höchsten Werthe, der Grösse k einen hohen Betrag beilegen zu dürfen.*

Unter der Voraussetzung also, dass k für das flüssige Magma der Erde einen durchaus hohen, mit der Tiefe wohl wachsenden Werth besitze, denken wir uns den ganzen linsenförmigen Raum um die Sonne, innerhalb dessen die Planeten umlaufen, als ein grosses Magnetfeld, erzeugt durch die übereinstimmend von West nach Ost verlaufenden Rotationen and Revolutionen der Himmelskörper mit ihren sich weit ausbreitenden, in einer gemeinsamen Weltraumatmosphäre sich vermischenden Atmosphären. Die Polarlichter der Erde und die Bildung des Rings um den Saturn scheinen anzudeuten, dass in grösserer Höhe der Planetenatmosphären die Stärke dieses primären Magnetfeldes besonders hohe Beträge besitze.

Aber diese in Richtung von Süd nach Nord aufsteigenden Kraftlinien bilden nur gleichsam die Hälfte des primären Feldes, sie erfordern ihren Zusammenschluss duch eine absteigende Bewegung. Dazu dienen die gut leitenden Massen der Sonne, der Planeten und vielleicht auch der Satelliten, welche sich, ihren Rotationsenergien entsprechend, in das grosse Gesammtfeld theilen. Nicht durch eine Sonnenferne ist das Magnetfeld der Erde von dem der Sonne geschieden, beide berühren sich, soweit nicht Merkur und Venus mit ihren Feldern dazwischen treten. Die Störungen im grossen Sonnenfelde bewirken Grenzverschiebungen zwischen den Feldern aller Einzelgebiete.

Die durch die Erde absteigenden Kraftlinien suchen als Weg des kleinsten Widerstands den längsten Weg durch die leitende Masse, die Axe. Sie convergiren von aussen gegen die Umgebung des Pols als die Gegend kleinster Geschwindigkeit der rotirenden Atmosphäre und somit kleinster magnetomotorischer Gegenkraft gegen ihre absteigende Richtung. Als unverkennbares Anzeichen der guten Leitungsfähigkeit des Erdinnern zeigt der verschiedene Widerstand der Erdkruste einen bedeutenden Einfluss auf die Dichte der ein- und austretenden Kraftlinien, denn die Maxima der Intensität liegen nicht an den mit Wasser oder Eis bedeckten Polen, sondern gegen die besser leitenden Festländer hin, gleich wie umgekehrt die Minima der Intensität im äquatorealen Gebiete über den Oceanen ihren Sitz haben. Dieses die Seele der Erde durchschneidende Kraftfeld inducirt nun in dem magnetischen Magma ein secundäres Kraftfeld, dessen Kraftlinien nur zum Theil aus der Erde austreten und sich mit denen des primären Feldes zu einem gemischten Felde combiniren. Zum grossen Theil verlaufen sie in sich selbst zurückkehrend im Innern tief unter dem Aequator, ihr System ist gleichwerthig mit einem mächtigen elektrischen Strom, der die Erdaxe in der Richtung von Ost nach West umkreist. Jede Verstärkung oder Schwächung des primären Feldes wird eine Verschiebung des secundären von der Axe weg oder zur Axe hin zur Folge haben. *Ein Aufhören des primären Feldes hätte den vollständigen Zusammenschluss aller Kraftlinien des Magmas im Innern der Erde zur Folge, so wie in einem der Induction entzogenen Stück weichen Eisens die Molecüle sich in Ringe ordnen müssen mit in sich selbst zurücklaufenden Kraftlinien ohne äussere magnetische Wirkung.*

Nur wenn die ganze Ursache des Erdmagnetismus ausser der Erde liegt, wird es selbstverständlich, dass auch die Ursachen der Störungen ausserhalb liegen. Dass diese äusseren Störungen bis zu Beträgen anwachsen können, welche ganz erhebliche Bruchtheile der magnetischen Gesammtkraft darstellen (1/30 bis 1/20 bei den stärksten magnetischen Gewittern), erscheint nur so lange unwahrscheinlich, als man den ostwestlichen inneren Erdstrom als primum movens des Erdmagnetismus betrachtet. *Alle die scheinbaren Widersprüche heben sich durch die Verlegung der Ursache nach aussen.*

Die Annahme, dass der Magnetisirungsfactor des Erdmagmas einen sehr hohen Werth besitze, ist das Mittel, um allen Räthseln der erdmagnetischen Erscheinungen eine einheitliche Erklärung zu geben.

The keynote to August Schmidt's theory is thus found to be, "the hypothesis that the Earth has a very high magnetic permeability affords the means for a uniform explanation of all problems of terrestrial magnetic phenomena." It will be seen that he ascribes an extra-terrestrial origin to the lines of magnetic force just as I do; we differ only as to details.

It may be worth while to remark that my own conclusion as given in No. III was reached before becoming thoroughly familiar with August Schmidt's papers, copies of which, in response to my request, were courteously supplied when No. III was already in press; hence no acknowledgment could be made in that number.

49. Perhaps we should not forget to observe the caution expressed by Robert Boyle against taking too decided a stand on a theoretical question: "having met with many things for which I could assign no probable cause, and with some for which many different ones might be alleged, I dare speak positively and confidently of very few things except of matters of fact."

However, as has been well said by another writer in a different connection, though quite *apropos* here also, "a subject so profound and so significant will not yield up its secret at the behest of a timid or half-hearted inquirer. Nor will it fail to confound the presumption born of an inadequate sense of the difficulties of the inquiry. There is need of audacity, and there is need of caution: it would be hard to say which is the more indispensable to success in an investigation so arduous yet so alluring."

To afford opportunity for discussion, I will accordingly continue to hold the view that the prime origin of the Earth's magnetism is to be sought outside and hope to present in the following number all the facts known to me bearing on the question at issue. The argument will be based on the results as already derived in my series of papers on the Physical Decomposition of the Earth's Magnetic Field, and upon some new ones not published as yet. The problem of the physical interpretation of the component parts of the permanent terrestrial field has engaged my attention, off and on, for almost two decades; evidence will be given that some definite progress has been made in this direction. The results of chief interest here are those deduced in PD No. II (*Terr. Mag.*, v. 6, 13-24). The significance of the facts found in that paper have thus far escaped attention; they afford evidence of the deflecting, turning, or displacing effect on the terrestrial lines of magnetic force by the Earth's rotation, and just what that signifies it will be the endeavor to explain in the proposed number.

The close relationship between some of the phenomena of the permanent magnetic field and those of the transient fields or of the variation ones will again become evident. The inquiry will be raised, for example, as to whether the lunar-diurnal magnetic variation may not possibly be explained by Foucault currents brought about by the tidal motion of conducting masses, chiefly of the oceans, across the terrestrial lines of magnetic force. The question of the existence of vertical Earth-air electric currents will also be found involved in the discussion.

Remarks on Theory of Magnetic Disturbances.

50. Prof. Adolf Schmidt of Potsdam, in his recent article, "Zur Frage der Zerlegung des erdmagnetischen Feldes", contained in the *Meteorologische Zeitschrift* for Febr., 1911, touches briefly on his own theory of magnetic disturbances. While not doubting that some magnetic disturbances can be attributed to cathode rays from the Sun in the manner supposed in Birkeland's theory, he says:

> .An investigation of magnetic disturbances extending now over several years has, however, strengthened me more and more in the conviction, that at least the principal part of these phenomena must stand in close relation to fixed conditions, greatly differentiated in space and connected with the Earth. The characteristic course of disturbances which in spite of apparent great diversity yet fundamentally presents great similarity may be explained most simply by the hypothesis that electric currents are here involved, which, as in the case of the diurnal variation, are induced by the Earth's vertical magnetic component, if there is set in motion in the outermost atmospheric layers, approximately along great circles, an explosively released vibration. Many disturbance diagrams, furthermore, either in their entirety or to greater or less extent, show so clearly corresponding symmetries of the form $f(t_0 + \tau) = -f(t_0 - \tau)$ that one is involuntarily reminded of a wave progressing to and fro. To explain the releasing of the vibration, one can hardly think of anything else than of the sudden entrance into the atmosphere of a cloud composed of electrified particles expelled by the Sun, an assumption against which, to be sure, weighty objections may be readily raised. A closer examination shows, however, that a comparatively small amount of such particles suffices, and this fact greatly diminishes the difficulties.

51. Schmidt promises a fuller exposition of his theory in the near future. It will be seen, however, even from this preliminary notice that he shares the view with Schuster and myself that solar phenomena are but the indirect causes of our magnetic storms; solar radiations bring about a releasing action of some kind in the upper atmospheric regions where is located the real seat of the energy involved in magnetic storms and not in the Sun. Chree has also raised some weighty objections against the very dominant part in the production of magnetic disturbances which Birkeland wishes to ascribe to direct effects from cathode rays, but his criticisms have thus far passed unnoticed by either Birkeland or his colleagues. See also the results of Schuster's calculations (§41).

As to the precise *modus operandi* by which the disturbance electric current systems are brought about overhead in order to produce the observed magnetic effects, there is abundant room for difference of opinion, especially because of our very limited knowledge of the physical conditions obtaining in the regions concerned. Originally I had the idea also that the disturbance currents were magneto-dynamically induced, as Schmidt supposes. In order to

get in this way the currents revealed by my mathematical analysis of simple positive magnetic perturbations (§36-38), it would be necessary to have the charged particles enter the Earth's magnetic field approximately along the magnetic meridians so as to be deflected by the vertical or total component in a direction roughly magnetically east and west and give ultimately a magnetic system whose axis was directed approximately north and south. I finally concluded, however, to drop all hypothesis and confine my attention entirely to an examination of the resulting current system.

52. To repeat: I start with an electric field already existing above us; if the strata in which the currents circulate are made more conducting by any cause whatsoever an extra current results which is the one concerned in the disturbances and which is subject to the same conditions as those controlling the primary currents. If this be true, then one might reasonably suppose that, as a first approximation, we should get a magnetic system having similar characteristics to the primary one; this I have shown to be actually the case, not contenting myself with merely a general consideration of the problem, but employing in my proof the method of the Gaussian analysis. (*Cf.* results in Table X, §36.) Others will find it very helpful to their understanding if they will themselves analyze similarly a typical magnetic disturbance. It may be pointed out here also by this intimate relationship between the outside permanent electric currents and the outside disturbance currents we can readily understand Adolf Schmidt's deduction respecting magnetic disturbances: "that at least the principal part of these phenomena must stand in close relation to fixed conditions, greatly differentiated in space and connected with the Earth."

The general impregnability of the position here taken will become more and more evident as the various numbers appear giving the facts now possessed. In conclusion, it may be pointed out that the correctness or incorrectness of the deductions respecting the non-simultaneity of sudden magnetic disturbances and their progression, as set forth chiefly in No. II, has nothing to do with the validity of the general theory of magnetic disturbances contended for in these papers. If continued investigations should confirm the deductions, then definite restrictions are set upon the altitude of the currents involved. It is hoped that before long another examination can be made with the aid of fresh data.

Washington, D. C., March 9, 1911.

EDMUND HALLEY.

Edmund Halley, the eminent astronomer and magnetician, was born at Haggerston, near London, England, on October 29, 1656. His early education was at St. Paul's School, after which he became a commoner at Queen's College, Oxford, in 1673, distinguishing himself both in the classics and mathematics; at nineteen he had already made important contributions to astronomy. In 1677 he made observations of southern stars on St. Helena Island, and on a continental tour beginning in 1680, he observed the great comet with Cassini at Paris; he married in 1682 Mary Tooke, daughter of an Auditor of the Exchequer. From this time on his scientific activities were many and varied; in 1684, in connection with studies of gravity, he consulted Newton and this led ultimately to his active part in the publication of the latter's "Pincipia"; in 1703 he was made Savilian Professor of Astronomy at Oxford, and in 1720 Astronomer Royal. He died in the full possession of his faculties on January 14, 1742.

Halley is known chiefly by reason of his astronomical work, but his achievements in the field of terrestrial magnetism, in which he became early interested, were equally epoch-making. In 1683 he published in the *Philosophical Transactions* "A Theory of the Magnetical Compass," and in 1692, also in the *Transactions*, "An Account of the Causes of the Change of the Variation of the Magnetic Needle." In these he rejected the then accepted hypothesis of one magntic axis as insufficint to explain the facts of terrestrial magnetism, and propounded that these facts led to "no other conclusion than that the whole globe of the Earth is one great magnet having four magnetic poles or points of attraction; near each pole of the equator two; and that in those parts of the world which lie near adjacent to any of these magnetic poles the needle is governed thereby, the nearest pole always being predominant over the more remote."

The interest arising from Halley's papers prompted the British Admiralty to commission him as the Captain of the "Paramour Pink" in August, 1698, and to give him instructions to take up what was probably the first purely scientific voyage. This voyage lasted for two years and extended over both the north and south Atlantic Oceans, from 50° north latitude to as far south as 52° latitude, and furnished the necessary material for what was to be the first chart of lines of "equal magnetic variation." The first isogonic chart issued by Halley had escaped the attention of modern magneticians until 1895, when a copy was found in the British Museum by Dr. L. A. Bauer (*Cf.* this Journal, vol. 1, pp. 28-31, where also a reduced facsimile reproduction is given). This chart covers approximately the region between 60° north latitude and 60° south latitude, and 30° east longitude to 100° west longitude. Singularly,

although Halley is generally credited with the invention of this very fruitful method of representing phenomena on the Earth's surface, he has apparently not published any paper dealing with the subject nor has he given the data on which the chart was based. The probable date of the first chart is 1701. The chart usually referred to as published in 1701, but which Dr. Bauer showed could not have appeared prior to 1702, is that entitled "A new and correct Sea Chart of the Whole World, shewing the Variations of the Compass as they are found in the year 1700." To Halley belongs also the credit for the first suggestion of the connection of the aurora borealis with the Earth's magnetism; see his paper in the *Philosophical Transactions* No. 347.

Halley in 1678 became a Fellow of the Royal Society, serving for a long period as its secretary and contributing in all 88 papers covering a variety of subjects.

HALLEY'S INSTRUCTIONS.[1]

"Whereas his Majesty has been pleased to lend his 'Pink the Paramour' for your proceeding with her on an expedition to improve the knowledge of the Longitude and variations of the Compasse, which shipp is now completely Man'd, Stored, and Victualled, at his Majesty's charge for the said Expedition: you are therefore hereby required and directed to proceed with her according to the following instructions:—

"You are to make the best of your way to the southward of the Equator, and there to observe on the East Coast of South America, and the West Coast of Africa, the variations of the Compasse with all the accuracy you can, as also the true situation both of Longitude and Latitude of the Ports where you arrive.

"You are likewise to make the like observations at as many of the islands in the seas between the aforesaid Coasts as you can (without too much deviation) bring into your Course; and, if the season of the year permit, you are to stand soe farr into the South till you discover the Coast of the Terra Incognita, supposed to lie between Mongolan's Straits and the Cape of Good Hope, which Coast you carefully lay down in its true position. In your return home you are to visit the English West India Plantations or as many of them as conveniently you may, and in them make such observations as may contribute to lay them down truely in their Geographicall Situation. And in all the Course of your voyage you must be carefull to omit no opportunity of noting the variation of the Compasse, of which you are to keep a Register in your Journal.

"You are, for the better lengthning out your Provisions, to put the men under your command when you come out of the Channel to six to four men's allowance, assuring them that they shall be punctually pay'd for the same at the end of the voyage.

"You are during the Term of this Voyage to be very carefull in conforming yourself to what is directed by the Generall Printed Instructions annexed to your Commission, with regard as well to his Majesty's honor, as to the Government of the Shipp under your command, and when you return to England, you are to call in at Plymouth, and, finding no order there to the contrary, to make the best of your way to the Downes, and remain there till further Orders: Giving us an Acct of your arrival."

[1] From *Knowledge*, May, 1910, to which source we are also indebted for Halley's portrait (Pl. III).

DIE MAGNETISCHE DEKLINATION IN TSINGTAU UND IHRE JÄHRLICHE ÄNDERUNG.

VON DR. B. MEYERMANN.

Im Laufe dieses Jahres wird das neue Observatorium in Tsingtau so weit fertiggestellt sein, dass mit der regelmässigen Beobachtung und Registrierung der 3 magnetischen Elemente begonnen werden kann. Seit mehreren Jahren wird die Deklination hier bereits beobachtet. Registrierungen finden jedoch erst seit April 1910 statt und diese sind nicht als vollwertig anzusehen, da die Variationsinstrumente vorläufig in einem alten Chinesenhause untergebracht sind, das noch zum Teil bewohnt ist. Zum Ableiten von Monats- und Tagesmitteln eignen sich die Kurven daher kaum. Es lassen sich jedoch brauchbare Tagesmittel aus ihnen ableiten für die Tage, an denen absolute Beobachtungen gemacht sind. Von Anfang April bis Ende Dezember 1910 ergeben sich so 31 Tageswerte, aus denen sich für 1910.6 die Deklination zu —3° 53′.7 ergiebt, wobei das Zeichen —, West Deklination bedeutet.

Dieser Wert bezieht sich jedoch nur auf einen für die Beobachtungen benutzten Pfeiler des Observatoriums. Die Umgebung von Tsingtau weist erhebliche Störungen des magnetischen Feldes auf; schon innerhalb des Observatoriumsgebietes treten starke Unterschiede auf. Der oben angegebene Wert kann daher nicht als Mittelwert für die nähere Umgebung von Tsingtau angesehen werden; der erstere scheint vielmehr einer kleinen Positionskorrektur zu bedürfen. Die bisher in der Umgegend von Tsingtau angestellten Beobachtungen sind noch zu unsystematisch verteilt, um aus ihnen die Korrektur ableiten zu können, so dass wir uns vorläufig mit dem obigen Resultate begnügen müssen. Zur Ableitung der jährlichen Änderung der Deklination kommen nur die auf dem gleichen Pfeiler angestellten Beobachtungen in Frage. Diese beginnen Ende 1905. Die bereits im Jahre 1899 während einiger Monate angestellten Beobachtungen sind hierzu nicht zu gebrauchen, da sie auf einem Pfeiler angestellt wurden, der abgerissen ist, ohne dass Vergleichsbeobachtungen mit dem neuen Pfeiler angestellt worden sind.

Die von dem Observatorium in Zi-ka-wei veröffentlichten stündlichen Werte der Deklination wurden dazu benutzt, um die Beobachtungen des Jahres 1906 auf das Jahresmittel zu reduzieren. Es ergiebt sich so aus 11 Beobachtungen das Jahresmittel für 1906.5 zu —3° 44′.6 ± 0.′2. Für 1910.6 war gefunden —3° 53′.7 (mit einem M. F. der sicher kleiner als ±0.′3 ist). Die mittlere jährliche Änderung ist somit —2.′2.

Tsingtau, 1911, Jan. 23.

[Observations were made at Tsingtau by the Carnegie Institution of Washington in 1908 on the pier of the German Observatory. The results, reduced to the International Magnetic Standards of the Department of Terrestrial Magnetism, are: declination, October 9, L. M. T. $15^h\,42^m$, 3°48′.5 west; dip, October 10, L. M. T. $9^h\,38^m$, 52°21′.5 north; and horizontal intensity, October 9, L. M. T. $15^h\,51^m$, 30766γ.]

NOTES

3. Distribution of Proceedings of Magnetic Commissions. Our attention has been called by a correspondent to the existence of an English version of the "Internationaler Meteorologischer Kodex", portions of which being specifically interesting to students of terrestrial magnetism and atmospheric electricity were translated into English in connection with the "Review", pp. 193-206, contained in the December, 1910, issue of the Journal. We do not know how far it was incumbent upon the Meteorological Committee to distribute among magneticians the English Codex; suffice it to say that the following are known not to have received copies: the Superintendent of the United States Coast and Geodetic Survey, the Director of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, and this Journal. If the English Codex is not for free distribution, then this fact should be made known so that copies may at least be purchased. *What is the purpose of holding conventions, if the results thereof are not to be made known in the freest and promptest manner possible?* [The above circumstance was submitted to Dr. Shaw. Under date March 3d he cordially states: "We are always glad to be of service where we can be, and with our new arrangements I am fortunately in a position to ask magneticians what institutes should be included in the list for the presentation of publications which are in any way concerned with magnetism." Hence those who may have use for the English "Codex" should apply directly to Dr. Shaw (Meteorological Office, South Kensington, London, S. W.)]

4. Terrestrial Magnetism and Atmospheric Electricity. On p. 206 of the December number of the Journal is recorded an action taken by the International Meteorological Committee at its Berlin meeting restricting the future work of its Commission on Terrestrial Magnetism and Atmospheric Electricity to Terrestrial Magnetism alone. The desirability of this step was not submitted to the Commission itself for an official expression of opinion, though several members of the Commission expressed themselves individually as in favor of it. Unfortunately as the motion was put, the impression is created that it was necessary to take the Commission to task for supposed inactivity in Atmospheric Electricity. It is difficult to see just what has been gained by the action; while another Commission, especially for Atmospheric Electricity, is contemplated, it was not formed, and when formed the chief result will be to make it increasingly difficult for the general body to reap full advantage of all its Commissions, already seven in number not counting the proposed new one. These Commissions are continually growing stronger, and it will be of interest to see whether they will continue to submit to actions taken by the parent Committee without previous

submission to them. Had the International Meteorological Committee requested the Commission here concerned to show cause why the subject of Atmospheric Electricity should continue to remain within its scope, some definite information would have resulted and a dangerous precedent would have been avoided.

5. *Work in Atmospheric Electricity.* The question as to what an institution can profitably undertake in atmospheric electricity would even to-day provoke considerable difference of opinion among the foremost investigators in this field. In 1899 when the establishment of five magnetic observatories under the United States Coast and Geodetic Survey was in contemplation, the following eminent men were asked for advice as to work in atmospheric electricity: von Bezold, Chree, Elster and Geitel, Mascart, Schuster, and Rücker. The general advice was to take up extensive work slowly, on the ground that the instruments and methods had not yet reached the required state of perfection. In 1905 these same gentlemen and in addition Ebert and Wiechert were once more consulted, this time with regard to the work of the Carnegie Institution of Washington. The general counsel, with but little variation, was almost the same as in 1899. Certain instruments, however, were ordered as the result of some specific advice, but by the time they were delivered they had been superseded in part or in whole by newer ones. The whole subject of measurements of Atmospheric Electricity is still, unfortunately, in a very unsatisfactory state, and the Commission on Terrestrial Magnetism and Atmospheric Electricity instead of being taken to task by the International Meteorological Committee for apparent inaction as far as Atmospheric Electricity is concerned, deserves instead praise for not having led the Meteorological Directors into undertaking possibly unprofitable work by passing immature resolutions.

While we are decidedly of the opinion that it is not advantageous either to Meteorology or to Terrestrial Magnetism to be pursued as though they were indissolubly related to one another, it is different with regard to Terrestrial Magnetism and Atmospheric Electricity; they mutually supplement one another in specific directions. In its broadest sense, Atmospheric Electricity ought to embrace the complete study of the whole electric field existing in the atmosphere. Unfortunately, however, the instruments of the atmospheric electrician bring us knowledge only of such currents as pass through his instruments or which are confined to but a very thin stratum above the surface. The effects of distant, overhead currents, more and more knowledge of which is being obtained almost daily, are measured well-nigh exclusively by the magnetician.

So again Terrestrial Electricity, where does this belong—to Terrestrial Magnetism or to Atmospheric Electricity? The most modern

treatises on the latter subject bring us surprisingly little information regarding the earth-currents, for example, brought into evidence during magnetic storms. So also with regard to Auroral Lights; this again is a field of inquiry of interest alike to the magnetician and to the electrician. *We should, therefore, have to view with some concern any proposed divorce between Atmospheric Electricity and Terrestrial Magnetism.* Let us hope that the action of the International Meteorological Committee is not a final one and that it will see its way to a reconsideration of its decision and to the full restoration of the Commission to its former powers!

6. Meteorological and Magnetic Institutions. Referring to the "Review" a correspondent, whose opinion we value highly, calls attention to the inutility of discussing the separation of meteorological and magnetic services. Though a meteorologist primarily, he takes no extreme view one way or the other, conceding that the connection of the two services under one organization in most countries has resulted chiefly from economical rather than from scientific reasons. This being a fact, why then agitate a change? is the line of his argument. We shall have to concede that there is much justice and sound common sense in this view. But simply because a thing has come to be, does it necessarily follow that it should continue so? If there is a distinct recognition of the needs of the Magnetic Department, no great harm is done, if for administrative purposes, it is put under the particular organization which can most successfully meet the responsibilities. One wonders, however, how in one country, for example, it happens that an aeronautical observatory is divorced from a meteorological establishment in its close proximity while a magnetic observatory and even a magnetic survey continue to remain as mere adjuncts to this same establishment. The main contention is that for the good of both sciences the magnetician and the meteorologist should not be forced into a subordinate attitude, the one to the other. If the meteorologist, for example, looks askance at the magnetician for not having done certain things, then in turn he can not legitimately object if some questions are asked of him. Why is it, for example, judging from past events, that it has been so difficult for the Meteorological Directors to put into execution the resolutions of one of its own Commissions? Does the fault here lie with the magnetician or with his chief, the Meteorological Director? Is it not but natural that such questions should be asked and to expect that they will continue to evoke inquiry?

7. Regarding an International Magnetic Union. The same correspondent referred to in the previous note likewise raises the question as to whether Terrestrial Magnetism would really fare better under the patronage of the International Association of Academies (*cf.* v. 15, pp. 205-6) than under the International Meteorological Committee. He

gives several weighty reasons for his doubts; we regret that we are not at liberty to print his letter.

8. The Passing of the Kew Magnetic Observatory. As known, electric car effects experienced at Kew necessitated the establishmnt of a new observatory at Eskdalemuir, Scotland, which, for various reasons, took longer to put into successful operation than need ordinarily have been the case. On July 1, 1910, the general control of the three observatories, Kew, Eskdalemuir, and Valencia, was assigned to the Meteorological Office, subject to the deliberations of the Gassiot Advisory Committee of the Royal Society. Just what magnetic work will continue to be carried out at Kew we have not yet seen announced. The testing and standardizing of magnetic instruments is shortly to be turned over to the National Physical Laboratory; it is to be hoped that this very important work will not be entrusted to one with experience simply in a physical laboratory, nor merely in an observatory, but to one who is also *practically* familiar with the conditions under which field work must be executed. At present improvements in magnetic instruments are being made chiefly by other countries.

The arrangements above will afford the present President of the International Meteorological Committee an admirable opportunity, which he no doubt will embrace, to bring magnetic observatory work in his country more in harmony with the various resolutions of the Magnetic Commission than has hitherto been the case. Thus, for example, no observatory inter-comparisons have emanated directly from Kew; the last ones, we believe, are those of Sir Arthur Rücker, made about 15 years ago. So also the fuller publication of observatory work will require his early consideration. Kew, furthermore, has no follower in its manner of applying the a-cyclic correction, the legitimacy of which may be open to question.

9. Magnetic Survey of North Germany for 1909.[1] This general survey, embracing about 400,000 sq. km., was executed between 1898-1903 by *Eschenhagen* and *Edler,* chiefly by the latter and according to the former's published plan; owing to their untimely death, the discussion and publication of the results fell to *Adolf Schmidt.* The present magnetic charts (*D, I, H*) apply to 1909.0 and are based on 265 stations, practically all trigonometric points and nearly uniformly distributed, there being one station to an area of about 1,500 sq. km.; the Potsdam Observatory served as base station for the entire region. (The present distribution of stations is thus about the same as in the United States Magnetic Survey, the results of which are being published *annually* at the rate of about 300 stations, or more.) More detailed work is left for the future as also final discussion and charts for the com-

[1] SCHMIDT, AD. Magnetische Karten von Norddeutschland für 1909. Veröff. Preuss. Met. Inst., No. 217, Berlin, 1910, pp. 40, pl. 4.

ponents (X, Y, Z for 1901.0). In affiliation with this survey, the other German States have already completed or are now making new magnetic surveys, some results for which have already been published by *Haussmann* (Württemberg and Hohenzollern), *Messerschmitt* (Bavaria), *Göllnitz* (Saxony), and *Nippoldt* (Baden, etc.). One important feature of Eschenhagen's plan, re-occupation of about 40 "repeat" stations, unfortunately, for various reasons, has only been partially carried out thus far. The secular and other corrections, accordingly, had to be deduced exclusively from Potsdam.

For such a comparatively restricted region, both methods of observation and of reduction could be simplified (*Cf.* pp. 12-36). In the case of larger regions it would not be possible, for example, to assume that the difference in a magnetic element between base station and a distant point remains constant even for such an interval of 1901 to 1909. On the average the corrections on account of diurnal variation were 0.'5 for D, 0.'2 for I, 2-3 γ for H, quantities negligible for practical purposes as Schmidt rightly says. All results were first reduced to 1901.0—the middle epoch of the survey, hence effect of some assumptions which had to be made will be diminished for this date. A careful investigation follows of all possible sources of error inclusive of the provisional reductions to 1909.0. It will be a matter of no little interest to see later how the finally reduced values, as dependent upon Potsdam alone, will agree with those derived when the data from the contemplated 40 repeat stations are available. The author's discussion should also convince others of the great importance of early publications of magnetic survey results, even though they be but provisional ones. The retention of much needed data for the sake of corrections which, in general, are subordinate to secular ones, or for the purpose of writing a learned memoir, appears, nowadays, unjustifiable. The author's good judgment must therefore be admired; without awaiting the outcome of a more elaborate discussion he immediately proceeds to the tabulation of the results and the construction of the iso-magnetic charts. The early completion of a general magnetic survey of the whole of Germany being assured, *let us hope that attention will next be paid to the German colonies!*

10. Personalia. Professor João Maria d'Almeida Lima entered in December last upon his duties as Director of the "Observatorio Meteorologico e Magnetico do Infante D. Luiz." *M. Roussilhe,* hydrographic engineer, expects to secure observations of magnetic declination and horizontal intensity on a mission of three years to the Congo, the Sangha and the Oubanghi; the magnetometer was supplied by *M. Angot's* Office. *L. A. Bauer* left Washington, March 16, via Vancouver, to meet the *Carnegie* at Colombo, Ceylon, due in June, returning to his office towards end of year.

11. The *Royal Academy of Sciences of Göttingen* proposes for the year 1913 the following problem: "The laws of the gradual change of moments of magnets are to be investigated." Prize, 1000 M.; date of delivery, February 1, 1913. The manuscripts are to be provided with a motto and address of author to be enclosed in sealed envelope forwarded to the Academy.

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PRAG STERNWARTE. Magnetische und meteorologische Beobachtungen an der k. k. Sternwarte zu Prag im Jahre 1909. L. Weinek, Direktor. Prag, K. K. Sternwarte, v. 70, 1910 (IV + 48).

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SCHMIDT, A. Die erdmagnetischen Elemente in Württemberg im Jahre 1910. Repr. Besonderen Beilage Staats-Anzeigers, Württemberg, Stuttgart, 1910 (8), 23 cm.

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Terrestrial Magnetism

and

Atmospheric Electricity

VOLUME XVI SEPTEMBER, 1911 NUMBER 3

MAGNETIC CHART ERRORS AND SECULAR CHANGES IN THE INDIAN OCEAN

By L. A. Bauer and W. J. Peters

In view of the exceptionally large errors in the most recent charts which are being disclosed in the Indian Ocean on the present cruise of the *Carnegie*, it was thought desirable to make early communication. Tables I and II give the values of the magnetic declination ("variation of the compass") with the geographic positions, as determined on the *Carnegie* from Cape Town to Colombo, Ceylon, thence to Mauritius, April to August, 1911; a future communication will give the results from Mauritius northward to the Arabian Sea, thence to Colombo and Batavia. While the present figures are not final, they are not likely to be changed by more than one-tenth degree.

The tables also give the corresponding values as scaled from the British Admiralty chart of 1907 (*B*); the German chart of 1910 (*G*); and the United States Hydrographic Office chart of 1910 (*U*); these chart values have been referred approximately to the time of our observations by applying the secular changes as indicated on the respective charts. The final three columns give the differences between the *Carnegie* values (*C*) and those of the various charts; the plus sign (+) means that the charts give west declinations too large, the minus sign (—) on the other hand signifying that the chart values are too low by the tabular amount.

It will be seen that, with the exception of a few values at the beginning of Table I, and at the end of Table II, the chart errors are always negative, and hence a value of west declination scaled from any one of the charts mentioned, as a rule, would have to be increased to make it correspond with that of the *Carnegie*. It will be noticed also that the errors run up at times to four degrees, and, for one of the charts, even to six degrees. These chart errors, while partly due to defective spacing of the lines of equal magnetic

declination, are to be referred chiefly to erroneous secular changes, applied to the previous data on which the charts depend; this is shown in Table III.*

The errors in the magnetic inclination reach a maximum of about three degrees, and in the horizontal intensity go up to a unit in the second decimal C. G. S. units.

TABLE *I.*

West Magnetic Declinations and Chart Errors, Cape Town to Colombo, May-June, 1911.

Date	Position		Carnegie	Chart Values			Chart Errors		
	Latitude	East Longitude		Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1911	° ′	° ′	°	°	°	°	°	°	°
Apr 28	38 26S	26 48	27.9	28.1	30.5	28.9	+0.2	+2.6	+1.0
30	39 55S	29 49	26.0	28.1	31.0	28.7	+2.1	+5.0	+2.7
May 3	39 47S	38 15	25.2	26.3	30.0	26.9	+1.1	+4.8	+1.7
10	40 16S	62 06	26.7	27.5	26.9	27.2	+0.8	+0.2	+0.5
10	40 18S	63 19	28.4	27.5	27.0	27.4	−0.9	−1.4	−1.0
11	40 18S	66 54	27.5	27.9	26.8	27.9	+0.4	−0.7	+0.4
11	40 15S	68 34	28.8	28.0	26.6	28.0	−0.8	−2.2	−0.8
12	39 52S	70 43	28.1	27.7	26.0	28.0	−0.4	−2.1	−0.1
12	39 26S	71 26	28.1	27.5	25.2	27.4	−0.6	−2.9	−0.7
13	39 13S	71 59	28.6	27.3	25.1	27.3	−1.3	−3.5	−1.3
13	39 17S	72 30	28.2	27.6	25.1	27.4	−0.6	−3.1	−0.8
14	39 23S	73 24	29.1	27.6	25.3	27.6	−1.5	−3.8	−1.5
15	39 50S	74 23	29.1	28.0	25.5	28.2	−1.1	−3.6	−0.9
17	38 36S	76 52	28.4	26.9	24.1	26.6	−1.5	−4.3	−1.8
19	35 16S	77 42	24.7	22.7	20.5	22.8	−2.0	−4.2	−1.9
20	34 09S	77 48	23.7	21.5	19.6	21.6	−2.2	−4.1	−2.1
21	32 08S	77 35	22.0	19.2	17.5	19.6	−2.8	−4.5	−2.4
22	28 54S	76 57	18.4	15.5	14.5	15.9	−2.9	−3.9	−2.5
24	24 16S	76 18	14.9	11.2	10.0	13.7	−3.7	−4.9	−1.2
25	21 22S	76 27	12.5	9.1	7.1	11.8	−3.4	−5.4	−0.7
26	19 16S	76 18	11.0	8.1	5.3	10.2	−2.9	−5.7	−0.8
26	19 06S	76 17	11.3	7.9	5.1	10.0	−3.4	−6.2	−1.3
27	18 45S	76 22	10.5	7.7	5.0	10.0	−2.8	−5.5	−0.5
27	17 52S	76 22	10.5	7.5	4.6	9.1	−3.0	−5.9	−1.4
28	16 02S	76 12	9.2	7.0	4.2	7.7	−2.2	−5.0	−1.5
28	14 56S	76 01	8.8	6.6	3.9	6.9	−2.2	−4.9	−1.9
29	13 03S	75 48	7.7	6.1	3.5	5.7	−1.6	−4.2	−2.0
29	11 53S	75 48	7.3	5.7	3.2	5.4	−1.6	−4.1	−1.9
30	10 36S	75 46	6.5	5.3	3.0	5.0	−1.2	−3.5	−1.5
30	9 38S	75 50	6.2	5.0	2.8	4.7	−1.2	−3.4	−1.5
31	8 03S	75 53	5.5	4.5	2.6	4.0	−1.0	−2.9	−1.5
31	6 54S	75 50	5.4	4.2	2.5	3.6	−1.2	−2.9	−1.8
Jun 1	4 50S	75 46	4.6	3.8	2.2	3.0	−0.8	−2.4	−1.6
2	3 22S	76 10	3.7	3.5	1.9	2.5	−0.2	−1.8	−1.2
2	2 17S	76 27	4.0	3.2	1.7	2.2	−0.8	−2.3	−1.8
3	0 39N	76 26	3.2	2.7	1.4	1.7	−0.5	−1.8	−1.5
5	3 39N	77 13	2.7	2.1	1.0	1.3	−0.6	−1.7	−1.4
6	5 16N	78 06	2.1	1.6	0.8	1.0	−0.5	−1.3	−1.1

* As some support to the last value of the table, it may be stated that west declination is at present increasing, as recorded at the Royal Alfred Observatory, Mauritius, at the rate of about two minutes per annum.

Secular Changes

From a comparison of the Carnegie values with those of the German Antarctic ship, the *Gauss*, made in 1903, by Dr. Bidlingmaier, the following values for the secular change result at points common to the two vessels.

The final three columns give the average annual change in the magnetic declination, first as resulting from a comparison of the results obtained on the *Gauss* (1902–3) and on the *Carnegie* (1911), next as shown, respectively, on the British Admiralty chart of 1907, and the United States Hydrographic Office chart of 1910—no values are found on the German chart. It will be seen that the charts give considerably smaller changes, and in the last case, of reversed sign.

TABLE *II.*

West Magnetic Declinations and Chart Errors, Colombo to Mauritius, June-August, 1911.

Date	Position		Carnegie	Chart Values			Chart Errors		
	Latitude	East Longitude		Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1911	° ′	° ′	°	°	°	°	°	°	°
Jul 8	5 25N	79 44	2.1	1.5	0.7	0.8	—0.6	—1.4	—1.3
8	4 49N	80 13	2.3	1.7	0.8	0.9	—0.6	—1.5	—1.4
9	4 05N	81 06	2.4	1.8	0.8	1.0	—0.6	—1.6	—1.4
10	2 24N	82 46	2.5	2.1	0.9	1.1	—0.4	—1.6	—1.4
10	1 40N	83 29	2.7	2.1	0.9	1.2	—0.6	—1.8	—1.5
11	1 10N	84 19	2.6	2.2	0.9	1.3	—0.4	—1.7	—1.3
12	0 54N	85 28	2.5	2.1	0.9	1.3	—0.4	—1.6	—1.2
13	1 10N	84 22	2.5	2.1	0.9	1.3	—0.4	—1.6	—1.2
14	1 07N	84 44	2.6	2.1	0.9	1.3	—0.5	—1.7	—1.3
15	0 34N	85 51	2.5	2.1	1.0	1.3	—0.4	—1.5	—1.2
16	0 02S	86 36	2.6	2.1	1.0	1.4	—0.5	—1.6	—1.2
17	1 22S	87 13	2.9	2.3	1.0	1.7	—0.6	—1.9	—1.2
18	2 52S	87 58	2.9	2.5	1.1	2.0	—0.4	—1.8	—0.9
19	3 49S	88 06	3.0	2.6	1.2	2.0	—0.4	—1.8	—1.0
21	6 32S	86 49	4.0	3.4	1.8	2.8	—0.6	—2.2	—1.2
22	8 52S	85 03	5.2	4.0	2.2	3.9	—1.2	—3.0	—1.3
23	11 02S	83 02	6.3	4.9	2.7	4.7	—1.4	—3.6	—1.6
24	12 51S	80 54	7.7	5.8	3.2	5.6	—1.9	—4.5	—2.1
25	14 58S	79 06	8.6	6.6	3.7	6.7	- 2.0	—4.9	—1.9
26	16 55S	77 13	10.0	7.2	4.3	8.2	—2.8	—5.7	—1.8
27	18 26S	75 00	10.7	7.9	5.0	9.7	—2.8	—5.7	—1.0
28	20 16S	72 29	11.9	8.6	6.6	10.8	—3.3	—5.3	—1.1
29	21 29S	70 28	11.9	9.6	7.9	11.4	—2.3	—4.0	—0.5
30	23 07S	68 26	13.3	10.8	10.0	13.0	—2.5	—3.3	—0.3
31	24 00S	65 56	13.2	11.2	11.1	13.0	—2.0	—2.1	—0.2
31	24 18S	65 14	13.2	11.5	11.3	13.0	—1.7	—1.9	—0.2
Aug 1	25 34S	63 52	14.0	12.6	12.7	13.9	—1.4	—1.3	—0.1
1	26 01S	63 15	14.1	13.1	13.0	14.1	—1.0	—1.1	0.0
2	25 51S	61 35	13.9	13.0	12.9	13.8	—0.9	—1.0	—0.1
2	25 36S	60 26	13.5	12.6	12.9	13.0	—0.9	—0.6	—0.0
3	24 58S	58 38	12.6	12.4	12.9	12.5	—0.2	+0.3	—0.1
3	24 08S	58 01	12.3	11.9	12.6	11.9	—0.4	+0.3	—0.4
4	23 00S	57 55	10.8	11.0	11.3	10.8	+0.2	+0.5	0.0
5	20 35S	57 54	9.1	10.0	9.5	8.6	+0.9	+0.4	—0.5
5	20 02S	57 31	9.2	9.0	9.0	8.3	—0.2	—0.2	—0.9

The plus sign (+) attached to the secular change means west declination is at present increasing for the locality shown; the minus sign (—) meaning, of course, the reverse. The large changes and their rapid variation with geographic position should be especially noted.

Unfortunately the *Gauss* results were not published until but a short time ago, and were hence not available before the *Carnegie* set out from Cape Town for Colombo, otherwise her route could have been arranged to secure more common points with those of the *Gauss* than those for regions *A* and *B*. However, before leav-

TABLE *III*.

Some Secular Changes in the Magnetic Declination in the South-eastern Part of the Indian Ocean.

Year and decimal	Latitude South	Longitude East of Gr.	West Declination	Vessel	Average Annual Change		
					Carnegie —Gauss	Chart Values	
						B '07	U '10
	° ′	° ′	°		′	′	′
1902.45	37 32	25 48	28.52	Gauss, mean of 10 stations			
1911.38	37 26	25 56	26.92	Carnegie " " 5 "			
Region A	37 29	25 52			—10.9	—2.8	—2.2
1903.32	35 17	74 47	22.84	Gauss, mean of 7 stations			
1911.38	35 16	74 44	24.61	Carnegie, " " 12 "			
Region B	35 16	74 46			+13.2	+2.6	+2.5
1903.35	25 14	60 36	12.65	Gauss, mean of 4 stations			
1911.58	25 19	60 35	13.34	Carnegie, " " 6 "			
Region C	25 17	60 35			+ 5.4	—2.2	—2.3

ing Colombo for Mauritius, we fortunately had received the publication containing the valuable results obtained on board the *Gauss*,[1] and accordingly our route was changed sufficiently to secure observations in the region *C*, which, as shown in the above table, will assist materially in defining the locality where the secular change passes through a zero value and then changes sign.

On Board the Carnegie,
Mauritius, August 6, 1911.

[1] Deutsche Südpolar-Expedition, 1901-1903. V. Erdmagnetismus. I. Erdmagnetische See-Beobachtungen und anschliessende Untersuchungen, von Dr. Friedrich Bidlingmaier. II. Teil, Deklination. Berlin, 1911.

COMPARISONS OF MAGNETIC OBSERVATORY STANDARDS BY THE CARNEGIE INSTITUTION OF WASHINGTON. No. II.

By J. A. Fleming.

Potsdam Observatory.

All observations here were made on what is called "Pier No. 5." There was no exchange of stations as the Observatory authorities had already made tests showing that station differences were negligible. The values given for Potsdam are based on the final determinations of base lines.

In connection with the horizontal intensity work it is interesting to compare the results with the differences obtained at Samoa, where the attempt is to have the same standard as at Potsdam, with the difference obtained by Dr. Linke[11] at the Cheltenham Observatory in 1904, with a Tesdorpf magnetometer standardized at Potsdam. The results at Samoa, as given later, give the difference (*C. I. W.-Samoa*) = (*C. I. W.-Potsdam*) = +0.00045*H*, this value being determined from only two sets of observations on one day. The difference Cheltenham-Potsdam, as determined by Dr. Linke from but one day's observations, Nov. 20, 1904, is +0.00169*H;* the difference (*C. I. W.-Cheltenham*), as shown below, is —0.00081*H;* hence indirectly (*C. I. W.-Potsdam*) = +0.00088*H*. The value determined by the Department directly is +0.00024*H*, resulting from several days' work. The differences between the two indirect determinations and the value obtained directly must be regarded on the whole as fairly satisfactory in view of the comparatively few observations on which the indirect determinations depend and from which they result, and because of the several steps involved. The value as directly observed, viz., +0.00024*H*, has been adopted. In further reference to this matter see also the results obtained by intercomparisons made by Dubinsky and Kühl, on page 157.

The result for difference in dip standards and accordingly the accuracy of dip circle 177 is also to be noted. On February 9, 16, 19, 1907, earth inductor No. 48 (Schulze) was tested at Potsdam

[11]Vergleich der Messung der Horizontalintensität des Erdmagnetismus in Potsdam und Cheltenham im Jahre 1904. *Nach. d. K. Gesell. d. Wissenschaften zu Göttingen; mathematisch-physikalische Klasse*, 1907.

with the standard of the Potsdam Observatory, inductor No. 1. The results were as follows, as per report of March 2, 1907, by Dr. Venske, assistant:

Feby. 9, 1907	(Ind. 1 — Ind. 48) =	—0.′26
" 16, 1907		—0. 26
" 19, 1907		—0. 28

Thus the mean difference (Potsdam minus inductor 48) is —0.′27. The standard in dip for the Department as stated above is inductor 48 decreased by 0.′5; whence correction to *C. I. W.* in dip for Potsdam standard would be —0.′2; the difference actually found by this direct comparison was (*C. I. W.-P.*) = —0.′3.

Results of Declination Comparisons at Potsdam Observatory.
(C. I. W. magnetometer 5)

Date		Local mean time From	Local mean time To	Declination obtained C. I. W.	Declination obtained Potsdam	C. I. W.—P.
1910		h m	h m	° ′	° ′	′
February	21	14 29	14 38	—9 08.4	—9 08.4	0.0
		16 44	16 53	03.6	03.9	+0.3
	22	8 17	8 26	04.1	04.6	+0.5
		10 22	10 31	05.5	06.2	+0.7
		10 48	10 57	06.4	07.0	+0.6
		12 27	12 36	08.0	08.2	+0.2
		14 30	14 39	08.4	08.8	+0.4
		16 22	16 31	07.5	07.3	—0.2
	23	12 04	12 13	08.7	09.1	+0.4
		13 53	14 02	08.3	08.8	+0.5
	24	8 21	8 30	04.4	04.6	+0.2
		10 01	10 10	04.2	04.5	+0.3
		10 22	10 31	04.6	05.2	+0.6
		12 02	12 11	09.1	09.3	+0.2

Mean value (C. I. W.—P.) = +0.′3; P. E. = ±0.′04.

Results of Horizontal Intensity Comparisons at the Potsdam Observatory.
(C. I. W. magnetometer 5)

Date		Local mean time From	Local mean time To	Horizontal intensity obt'd C. I. W.	Horizontal intensity obt'd Potsdam	C. I. W.—P.
1910		h m	h m	γ	γ	γ
February	21	14 50	16 39	18833	18830	+ 3
	22	8 31	10 18	846	835	+11
		11 01	12 24	827	830	— 3
		14 44	16 17	840	835	+ 5
	23	12 18	13 49	830	825	+ 5
	24	8 34	9 59	854	845	+ 9
		10 34	11 59	837	835	+ 2

Mean value (C. I. W.—P.) = +4.6γ; P. E. = ±1.0γ.
or +0.00024*H*; P. E. = ±0.00005*H*.

Results of Inclination Comparisons at Potsdam Observatory

(C. I. W. dip circle Dover 177)

Date	Local mean time From	Local mean time To	Needle	Inclination obtained C. I. W.	Inclination obtained Potsdam	C. I. W.—P. Needle 1	2	5	6
1910	h m	h m		° ′	° ′	′	′	′	′
Feb. 24	15 16	16 37	1	+66 19.1	+66 19.1	0.0			
	15 24	16 29	2	18.9	19.3		−0.4		
	15 33	16 19	5	18.9	19.2			−0.3	
	15 42	16 07	6	19.3	19.2				+0.1
25	9 02	10 22	1	21.3	21.3	0.0			
	9 11	10 11	2	20.9	21.4		−0.5		
	9 22	10 02	5	21.4	21.3			+0.1	
	9 31	9 53	6	20.1	21.4				−1.3
	14 24	15 49	1	22.3	21.7	+0.6			
	14 34	15 40	2	20.2	21.6		−1.4		
	14 43	15 30	5	21.4	21.6			−0.2	
	14 53	15 19	6	21.5	21.5				0.0
	15 58	17 26	1	23.1	23.8	−0.7			
	16 10	17 14	2	22.4	23.9		−1.5		
	16 20	17 04	5	23.1	24.1			−1.0	
	16 30	16 55	6	24.5	24.5				0.0
28	9 12	10 38	1	19.8	20.2	−0.4			
	9 21	10 26	2	18.7	20.2		−1.5		
	9 31	10 14	5	19.8	20.2			−0.4	
	9 40	10 03	6	20.4	20.2				+0.2
	11 24	12 46	1	19.7	19.8	−0.1			
	11 36	12 37	2	19.3	19.8		−0.5		
	11 44	12 25	5	19.9	19.8			+0.1	
	11 54	12 17	6	19.9	19.7				+0.2
	15 26	16 58	1	20.0	20.5	−0.5			
	15 35	16 48	2	19.7	20.3		−0.6		
	15 52	16 40	5	20.1	20.5			−0.4	
	16 06	16 31	6	21.0	20.4				+0.6
				Means,		−0.2	−0.9	−0.3	0.0

Mean value (C. I. W.—P.) = −0.′3; P. E. = ±0.′1.

Tiflis Observatory.

The comparisons of 1909 were made at three stations: the north pier of absolute house (also used in 1908), the outside station of 1908, and west pier in field (not occupied in 1908). At the time of writing the Observatory results for the 1909 work have not been received. In the meantime the difference in declination is accepted as in the first publication of comparisons. The slight alteration due to final adjustments of constants modify the intensity and dip differences from the first results to: H, ($C.\ I.\ W.$—$T.$) = +0.0004H, P. E. = ±0.00004H; I, ($C.\ I.\ W.$—$T.$) = −1.′6, P. E. = ±0.′1.

The detailed tables will be published for both series when the Observatory data are received.

Melbourne Observatory.

The north and south piers of the absolute house of the Melbourne Observatory were occupied; the former is used for magnetometer and the latter for dip circle work. In these observations magnetometer Tesdorpf No. 2025 was used. There is, however, some uncertainty regarding the constants of these instruments during the latter part of the campaign with them, and for this reason only the dip results as obtained with circle 171 are noted, pending additional intercomparisons with standard instruments which will be made in connection with the magnetic survey of Australia.

Results of Inclination Comparisons at the Melbourne Observatory.

(C. I. W. dip circle Dover 171)

Date	Local mean time		D. C. 171 needle	Inclination obtained		C. I. W. —M.	Remarks
	From	To		C. I. W.	Melbourne		
1906	h m	h m		° ′	° ′	′	
Nov. 20	7 28	8 28	5 & 6 of 172	—67 35.5	—67 34.5	—1.0	171 on south
23	10 38	11 25	"	36.3	36.9	+0.6	pier absolute
24	10 00	10 44	"	37.2	36.7	—0.5	house

Mean value (C. I. W.—M.) = —0.′3; P. E. = ±0.′3.

Tashkent Observatory.

The Observatory data have not yet been received.

Cheltenham Observatory.

All the observations at the Cheltenham Observatory have been made on the dip circle pier in the west wing of the absolute house. Careful determinations made by the Observatory authorities indicate that there is no difference for the magnetic elements between this pier and those piers upon which the permanent observatory instruments are mounted.

The standards at this Observatory, which is the base station of the United States Coast and Geodetic Survey, fix also those for the observatories of that Bureau at Honolulu, Vieques (Porto Rico), Baldwin (Kansas, now discontinued and superseded by Tucson, Arizona), and Sitka (Alaska). For this reason the details of the comparisons made at these points by the Department are not published; it may be stated, however, that the results confirm closely the fact that the standards are identical for the five observatories.

Results of Declination Comparisons at the Cheltenham Observatory.

(C. I. W. magnetometer 5 for I & III and C. I. W. magnetometer 7 for II)

Series	Date	Local mean time From	Local mean time To	Declination obtained C. I. W.	Declination obtained Cm.	C. I. W. −Cm.	Remarks
	1908	h m	h m	° ′	° ′	′	
I	Feb. 5	13 32	13 41	−5 31.2	−5 31.9	+0.7	
		15 33	15 42	35.4	36.0	+0.6	
	6	8 08	8 14	25.6	25.5	−0.1	
		10 16	10 22	26.0	26.4	+0.4	
		11 40	11 47	27.7	28.2	+0.5	
	7	11 13	11 20	26.5	26.0	−0.5	
		14 19	14 26	32.2	32.3	+0.1	
		14 34	14 40	33.3	33.1	−0.2	
		15 56	16 03	30.7	31.6	+0.9	
		16 06	16 13	31.3	31.9	+0.6	
		16 16	16 22	31.6	32.2	+0.6	
	8	8 34	8 40	25.1	25.2	+0.1	
		10 28	10 34	25.0	24.9	−0.1	
						+0.3	P.E. = ±0.′08
II	Mch. 24	11 18	11 27	−5 29.6	−5 29.4	+0.2	
		15 16	15 25	32.8	32.7	+0.1	
		15 39	15 45	32.8	32.5	+0.3	
	25	7 51	8 00	25.7	25.8	−0.1	
		10 12	10 21	27.3	26.9	+0.4	
		15 42	15 50	34.6	34.2	+0.4	
		16 26	16 35	32.9	33.1	−0.2	
	26	7 53	8 02	27.2	27.2	0.0	Obs'ns after 9h 20m on Mch. 26 to 11h 28m on Mch. 27 not used, as magnetic storm on.
						+0.1	P.E. = ±0.′05
	1910						
III	Apr. 5	13 04	13 13	−5 46.1	−5 46.2	+0.1	
		14 39	14 48	44.8	45.0	+0.2	
		15 00	15 09	44.5	44.4	−0.1	
		16 30	16 39	41.5	41.9	+0.4	
	6	7 25	7 34	36.7	37.0	+0.3	
		9 22	9 31	37.4	37.4	0.0	
		9 41	9 50	38.0	38.2	+0.2	
		11 13	11 22	43.4	43.8	+0.4	
		11 37	11 46	44.8	44.5	−0.3	
		14 38	14 47	44.5	44.9	+0.4	
		14 57	15 06	44.1	44.2	+0.1	
		16 28	16 37	40.7	40.9	+0.2	
						+0.2	P.E. = ±0.′04

Weighted mean value (C. I. W.—Cm.)
from I, II, and III = +0.′2; P.E. = ±0.′02.

Results of Horizontal Intensity Comparisons at the Cheltenham Observatory.

(C. I. W. magnetometer 5 for I & III, C. I. W. magnetometer 7 for II)

Series	Date	Local mean time From	Local mean time To	Horizontal intensity obtained C. I. W.	Horizontal intensity obtained Cm.	C.I.W.-Cm	Remarks
	1908	h m	h m	γ	γ	γ	
I	Feb. 5	13 47	15 30	19936	19951	−15	
		15 55	17 04	926	946	−20	
	6	8 18	10 07	930	946	−16	
		10 25	11 33	902	919	−17	
	7	11 22	14 09	902	925	−23	
		14 43	15 52	912	935	−23	
	8	8 44	10 20	939	954	−15	
						−18.4γ	P. E. = ±0.9γ
II	Mch. 24	13 28	15 10	19931	19950	−19	
		15 51	16 56	940	965	−25	
	25	8 13	9 35	930	954	−24	
		12 56	14 29	947	964	−17	
		14 57	16 17	956	976	−20	
	26	8 13	9 35	938	960	−22	
		10 40	11 38	938	949	−11	
		14 01	15 17	869*	883*	−14	*Magnetic storm
	27	8 17	9 27	922	933	−11	on
		10 07	11 13	879*	901*	−22	
						−18.6γ	P. E. = ±1.1γ
	1910						
III	Apr. 5	13 22	14 37	19817	19831	−14	
		15 14	16 28	831	846	−15	
	6	7 37	9 21	810	824	−14	
		9 53	11 11	790	806	−16	
		13 04	14 35	816	826	−10	
		15 09	16 23	822	838	−16	
						−14.2γ	P. E. = ±0.6γ

Weighted mean value (C. I. W.—Cm.) from
I, II, and III = −16.0γ; P. E. = ±0.5γ.
or −0.00081*H*; P. E. = ±0.00003*H*.

Results of Inclination Comparisons at the Cheltenham Observatory.

(C. I. W. dip circle Dover 177)

Series	Date	Local mean time From	Local mean time To	D. C. 177 needle	Inclination obtained C. I. W.	Inclination obtained Cheltenham	C. I. W.–Cm. 1	C. I. W.–Cm. 2	C. I. W.–Cm. 5	C. I. W.–Cm. 6
	1908	h m	h m		° ′	° ′	′	′	′	′
I	Feb. 4	10 42	11 50	1	+70 30.8	+70 31.5	−0.7			
		10 53	11 40	2	31.7			+0.2		
		11 00	11 34	5	31.3				−0.2	
		11 07	11 28	6	30.9					−0.6
	5	8 52	10 51	1	29.8	30.0	−0.2			
		9 03	10 44	2	31.3			+1.3		
		9 11	10 38	5	30.9				+0.9	
		9 19	10 30	6	30.0					0.0
	6	14 10	15 54	1	30.4	30.6	−0.2			
		14 18	15 46	2	31.7			+1.1		
		14 25	15 37	5	31.7				+1.1	
		14 32	15 32	6	32.1					+1.5
	7	8 42	10 30	1	29.8	30.3	−0.5			
		8 48	10 25	2	31.6			+1.3		
		8 56	10 16	5	30.6				+0.3	
		9 04	10 10	6	31.0					+0.7
					Means		−0.4	+1.0	+0.5	+0.4

Mean value (C. I. W.—Cm.) from I = +0.′3; P. E. = ±0.′2.

	1910									
II	Apr. 7	8 16	9 24	1	+70 35.0	+70 35.8	−0.8			
		8 24	9 16	2	35.4			−0.4		
		8 32	9 08	5	35.4				−0.4	
		8 40	9 01	6	36.2					+0.4
		10 09	11 15	1	36.4	35.9	+0.5			
		10 17	11 07	2	35.9			0.0		
		10 24	10 58	5	36.1				+0.2	
		10 33	10 51	6	36.4					+0.5
		13 00	14 21	1	36.2	35.3	+0.9			
		13 09	14 13	2	35.6			+0.3		
		13 18	14 04	5	35.4				+0.1	
		13 28	13 56	6	36.4					+1.1
		15 34	16 48	1	34.2	34.6	−0.4			
		15 42	16 39	2	33.7			−0.9		
		15 51	16 30	5	34.2				−0.4	
		16 00	16 21	6	34.9					+0.3
	8	8 10	9 18	1	35.9	35.9	0.0			
		8 18	9 11	2	35.8			−0.1		
		8 27	9 04	5	35.9				0.0	
		8 35	8 57	6	36.2					+0.3
		10 12	11 13	1	36.4	36.4	0.0			
		10 19	11 07	2	35.7			−0.7		
		10 26	11 00	5	35.9				−0.5	
		10 33	10 53	6	36.3					−0.1
					Means		0.0	−0.3	−0.2	+0.4

Mean value (C. I. W.—Cm.) from II = 0.′0; P. E. = ±0.′1.

Weighted mean value (C. I. W.—Cm.) from I and II = +0.1; P. E. = ±0.1.

Falmouth Observatory.

Simultaneous observatory values are not yet received.

Dehra Dun Observatory.

The observations at the Dehra Dun Observatory were made at both the north and south absolute houses with interchange of instruments and stations. The standards of the Observatory are for declination and horizontal intensity Cooke magnetometer 17 (Survey of India pattern), and for inclination earth inductor 30 (these are also the standards for the magnetic survey of India). Simultaneous observations were made with both outfits of absolute instruments. Some of the intensity results by magnetometer 17 not being entirely simultaneous have been referred to the same instant as the work with magnetometer 10 by use of the magnetograph curves. The Observatory values are corrected fully for both distribution coefficients of the magnets; the value of the moment of inertia of the oscillation magnet and suspension is that determined in September, 1909. In connection with the latter it is interesting to note that had the old value used previously to the September, 1909 determination been used the difference (*C. I. W.-D. D.*) would have been $+21.0\gamma$ or $+0.00063H$ instead of $+0.00159H$, and thus much nearer the provisional International Magnetic Standard.

Results of Declination Comparisons at the Dehra Dun Observatory.
(C. I. W. magnetometer 10)

Date	Local mean time From	Local mean time To	Declination obtained* C. I. W.	Declination obtained* Dehra Dun	C. I. W.—D. D.	Remarks
1910	h m	h m	° ′	° ′	′	
Oct. 20	16 15	16 22	+2 36.3	+2 36.5	—0.2	10 at S; 17 at N
21	12 41	12 48	32.0	31.5	+0.5	
	12 59	13 06	32.3	31.5*a*	+0.8	
23	10 49	10 56	36.4	34.1	+2.3?	Reject
	12 23	12 30	34.9	33.3	+1.6?	Reject
Oct. 21	14 31	14 38	+2 34.3	+2 34.5*a*	—0.2	10 at N; 17 at S
	15 57	16 06	35.2	35.0	+0.2	
22	7 08	7 17	34.7	34.9	—0.2	
	8 50	8 57	36.6	36.4*a*	+0.2	
	11 07	11 14	34.9	35.0	—0.1	
	12 37	12 44	33.7	33.3	+0.4	

Mean value (C. I. W.—D. D.) = +0.′2; P. E. = ±0.′1.

*All values reduced to station south house. S (S — N = +0.′4); N = north house.

a Values interpolated from observatory observations as no simultaneous results given at these times; differences resulting from these are weighted one-half in the mean.

Results of Horizontal Intensity Comparisons at the Dehra Dun Observatory.

(C. I. W. magnetometer 10)

Date	Local mean time From	Local mean time To	Horizontal intensity* obtained C. I. W.	Horizontal intensity* obtained Dehra Dun	C. I. W. —D. D.	Remarks
1909	h m	h m	γ	γ	γ	
Oct. 20	14 52	16 02	33232	33183	+49	10 at S; 17 at N
21	7 37	8 48	244	200	+44	
	11 21	12 35	297	233	+64	
23	10 57	12 07	228	172	+56	
Oct. 21	14 38	15 50	33268	33214	+54	10 at N; 17 at S
22	7 21	8 48	258	202	+56	
	11 15	12 28	262	214	+48	

Mean value (C. I. W.—D. D.) = +53.0γ; P. E. = ±1.7γ.
or +0.00159H; P. E. = ±0.00005H.

*There is no appreciable difference between the south house, S, and the north house, N.

Results of Inclination Comparisons at the Dehra Dun Observatory.

(C. I. W. dip circle Dover 171)

Date	Local mean time From	Local mean time To	Needles used in 171	Inclination obtained* C. I. W.	Inclination obtained* Dehra Dun	C. I. W. –D. D.	Remarks
1909	h m	h m		° ′	° ′	′	
Oct. 19	14 54	15 34	5 & 6 of 172	+43 58.5	+43 58.3	+0.2	171 at N; E. I.
	15 42	16 14	& 7 of 178	59.2	58.0	+1.2	30 at S
22	14 50	15 26	" "	54.3	54.0	+0.3	
Oct. 20	7 25	8 06	" "	+43 54.7	+43 53.9	+0.8	171 at S; E. I. 30
	8 16	8 56	" "	51.3	53.9	—2.6	at N
23	7 19	7 58	" "	53.2	53.4	—0.2	
	7 59	8 45	" "	53.2	53.8	—0.6	

Mean value (C. I. W.—D. D.) = —0.′1; P. E. = ±0.′3.

*The station difference is apparently negligible; S=south house, N=north house.

Helwan Observatory.

The result in declination for (*C. I. W.-H.*) = +0.′5 with a probable error of ±0.′1 is as already published in the first publication on comparisons. The final value of constants for horizontal intensity and inclination have slightly altered the differences in these elements as indicated in the tables herewith.

Results of Horizontal Intensity Observations at the Helwan Observatory.

(C. I. W. magnetometer 5)

Date	Local mean time From	Local mean time To	Horizontal intensity obtained C. I. W.*	Horizontal intensity obtained Helwan	C. I. W. —H.	Remarks
1908	h m	h m	γ	γ	γ	
April 22	15 19	16 57	30046	30027	+19	5 at N
23	9 21	10 14	40	31	+ 9	
24	15 42	17 04	38	36	+ 2	
25	8 59	10 23	40	36	+ 4	
April 26	15 36	17 08	30041	30032	+ 9	5 at A
27	9 09	11 16	59	42	+17	

Mean value (C. I. W.—H.) = 10.0γ; P. E. = ±1.9γ.
or +0.00033H; P. E. = ±0.00006H.

*Values all reduced to north pier absolute room, A (A—N = −6γ);
N = north pier porch; S = south pier porch.

Results of Inclination Comparisons at the Helwan Observatory.

(C. I. W. dip circle Dover 177)

Date	Local mean time From	Local mean time To	D.C. 177 needle	Inclination obtained C. I. W.*	Inclination obtained Helwan	C. I. W.—H. Needle 1	2	5	6
1908	h m	h m		° ′	° ′	′	′	′	′
April 21	16 14	16 59	1	+40 37.2	+40 37.2	0.0			
	16 23	16 48	2	38.0			+0.8		
23	11 47	13 14	1	37.8	37.5	+0.3			
	11 59	13 02	2	37.1			−0.4		
	12 09	12 53	5	38.0				+0.5	
	12 21	12 41	6	36.7					−0.8
	15 34	17 05	5	40.1	39.9			+0.2	
	15 49	16 51	6	39.7					−0.2
24	8 33	10 23	5	37.8	38.0			−0.2	
	8 43	10 14	6	40.3					+2.3?
	10 46	12 42	5	36.3	35.9			+0.4	
	10 58	12 34	6	39.5					+3.6?
25	11 19	12 57	1	38.3	37.6	+0.7			
	11 28	12 48	2	38.2			+0.6		
	15 10	16 52	1	39.5	38.7	+0.8			
	15 18	16 41	2	38.6			−0.1		
26	9 03	9 46	5	39.2	38.4			+0.8	
	9 13	9 37	6	37.9					−0.5
	10 50	11 35	5	37.4	37.4			0.0	
	11 01	11 23	6	37.1					−0.3
				Means		+0.4	+0.2	+0.4	−0.4

Mean value (C. I. W.—H.) = +0.′2; P. E. = ±0.′1.

? Values thus marked are rejected.

*Values all reduced to south pier porch, S (S—N = −0.′2); N = north porch pier. Observations of April 21-25 were all made at N; observations of April 26 were made at S.

Havana Observatory.

Two stations were occupied in the comparison of the instruments of the Havana Observatory (Observatorio del Colegio de Belen). The first was the absolute observing house at the College, while the second was located at the villa belonging to the College about three kilometers magnetically south of the College. An interchange of instruments and stations was made. In the compilations below some slight corrections on account of diurnal variation have been applied to the results with the Havana magnetometer and dip circle (needle 1) to reduce these to the same instant of time as those obtained with the Department outfit.

Results of Declination Comparisons with the Havana Observatory Instruments.
(Magnetometer U. S. C. & G. S. 19)

Date	Local mean time From	Local mean time To	Declination obtained* C. I. W.	Declination obtained* Havana	C. I. W. —Hav.	Remarks
1905	h m	h m	° ′	° ′	′	
May 19	10 00	10 09	+2 59.8	+2 59.8	0.0	19 at V; Hav. at C
	13 07	13 16	55.1	54.1	+1.0	
20	8 12	8 21	61.2	59.5	+1.7	
	13 10	13 19	53.5	51.1	+2.4	
25	8 02	8 11	59.6	60.2	—0.6	
	13 02	13 11	56.5	56.3	+0.2	
	14 16	14 25	56.9	55.3	+1.6	
May 22	13 37	13 46	+2 54.5	+2 53.6	+0.9	19 at C; Hav. at V
23	8 09	8 18	61.1	59.7	+1.4	
	13 11	13 20	57.1	55.4	+1.7	
	14 28	14 37	55.0	54.9	+0.1	

Mean value (C. I. W.—Hav.) = +0.′9; P. E. = ±0.′2.

*Values are all reduced to Colegio station, C (C—V=—1.′8); V=villa station. The observations with the Havana instruments in several cases are not quite simultaneous in time with 19; in these cases slight corrections to reduce to the same instant have been applied.

Results of Inclination Comparisons with the Havana Observatory Instruments.
(C. I. W. dip circle Dover 171)

Date	Local mean time From	Local mean time To	D.C.171 Needle	Inclination obtained* C. I. W.	Inclination obtained* Havana	C.I.W.—Havana	Remarks
1905	h m	h m		° ′	° ′	′	
May 19	15 10	15 32	1 & 2	+52 60.7	+52 58.5	+2.2	171 at V; Hav. at C
20	9 59	10 40	1 & 2	57.5	48.5	?	
	15 07	15 44	1 & 2	58.9	55.4	+3.5	
25	9 47	10 17	1 & 2	58.5	59.2	—0.7	
May 22	9 50	10 24	1 & 2	+52 58.4	+52 57.0	+1.4	171 at C; Hav. at V
	15 02	15 34	1 & 2	58.5	55.4	+3.1	
23	9 57	10 29	1 & 2	57.7	52.1	?	
	14 54	15 34	1 & 2	60.0	59.9	+0.1	

Mean value (C. I. W.—Hav.) = +1.′6; P. E. = ±0.′5.

*All results reduced to Colegio station C; C—V= —0.′9 (V=villa station). Slight corrections have been applied to reduce the Havana values to the same instant of time as those by 171.

Hongkong Observatory.

The observations at the Hongkong Observatory were made at the observing house and at an outside station distant 14.3 meters from the south pier in the observing house in true bearing south 2°09′ east of this pier. The standard Observatory instruments are Elliott magnetometer 55 and Dover dip circle 71 (needles 3, 4, 7, and 8). The north pier of the observing house is 2.25 meters from the south in true bearing north 2°09′ west of the latter; the first is used for magnetometer and the second for dip circle work. The Observatory also has an Elliott magnetometer 83 which, according to *Observations made at the Hongkong Observatory in the year 1899*, gives higher results than the standard 55 by 52 gammas. It thus appears that 83 is nearer the "International Magnetic Standard," as its correction would be, in horizontal intensity, according to differences obtained with 55, +30.8 gammas or +0.00083*H*.

The dip comparisons of December, 1908, were not satisfactory. Dip comparisons were, therefore, made at the first opportunity during March 1 to 6, 1911. Two stations were occupied, viz., *A′* and *B*. *A′* is the regular observatory dip pier in the absolute house, and *B* a tent station established south of the absolute house 14.30 meters distant from *A′*. The observations were made by one observer alternating between the two instruments set up at the two stations. The observations were made first with two needles of one instrument at one station, then with four needles of the other instrument at the second station, and then with the remaining two needles of the first instrument at the first station, thus making the mean times for each instrument at each intercomparison practically simultaneous. The correction of the mean of needles 1, 2, 5, and 6 of circle 206 is taken provisionally as —2.′0 at 30° north dip.

Results of Declination Comparisons at the Hongkong Observatory.
(C. I. W. magnetometer 10)

Date	Local mean time From	Local mean time To	Declination obtained* C. I. W.	Declination obtained* Hongkong	C. I. W. —Hong.	Remarks
1908	h m	h m	° ′	° ′	′	
Dec. 21	10 03	10 12	+0 06.3	+0 06.7	—0.4	10 at T; 55 at H
	16 14	16 23	05.9	....	.....	No obsns. by 55
23	9 12	9 21	06.4	04.9	+1.5	
Dec. 23	10 01	10 10	05.0	....	.....	10 at H; 55 at T;
	15 49	15 58	06.5	05.9	+0.6	no obsns. by 55
24	12 27	12 34	04.8	03.9	+0.9*a*	

Mean value (C. I. W.—Hong.) = +0.′6; P. E. = ±0.′3.

*All values reduced to hut station, H (H—T= +2.′2); T=tent station.

a Owing to indistinctness of mark used in observations by 55 this difference is weighted ½; correction has also been made to the value by 55 to reduce it to the same instant as observations by 10.

Results of Horizontal Intensity Comparisons at the Hongkong Observatory.

(C. I. W. magnetometer 10)

Date	Local mean time From	Local mean time To	Horizontal intensity* obtained C. I. W.	Horizontal intensity* obtained Hongkong	C. I. W. —Hong.	Remarks
1908	h m	h m	γ	γ	γ	
Dec. 21	11 36	13 02	37156	37074	+82	10 at T; 55 at H
	14 32	15 55	170	086	+84	
23	14 16	15 37	166	076	+90	10 at H; 55 at T
24	9 18	10 48	151	076	+75	

Mean value (C. I. W.—Hong.) $+82.8\gamma$; P. E. $= \pm 2.1\gamma$.
or $+0.00223H$; P. E. $= \pm 0.00006H$.

*All results are reduced to the hut, H (H—T——14γ); T—tent station.

Results of Inclination Comparisons at the Hongkong Observatory.

(C. I. W. dip circle Dover 206, needles 1, 2, 5, 6)

Date	Local mean time From	Local mean time To	Inclination obtained* C. I. W.	Inclination obtained* Honkong	C. I. W. —Hong.	Remarks
1911	h m	h m	° ′	° ′	′	
Mar. 1	10 03	14 55	+30 56.6	+30 58.2	—1.6	C. I. W. at B; Hong. D.
2	8 40	12 21	56.6	58.8	—2.2	C. at A′
	13 18	16 41	56.5	57.8	—1.3	
3	10 12	14 21	55.2	56.2	—1.0	C. I. W. at A′; Hong.
4	7 58	11 28	55.8	57.0	—1.2	D. C. at B
	12 28	17 23	56.0	56.9	—0.9	
5	10 12	14 41	55.4	55.4	0.0	C. I. W. at B; Hong. D. C. at A′
6	10 24	14 46	55.4	57.0	—1.6	C. I. W. at A′; Hong. D. C. at B

Mean value (C. I. W.—Hongkong) —1′.2 P. E. $= \pm 0.'2$.

*All values reduced to station A′ (A′—B—0.′7).

Alibag Observatory.

In a series of intercomparisons obtained at the observatory at Alibag, near Bombay, the stone pier, designated as *L*, with marble top, on the second or lower floor of the stone observing tower, and the center and south piers of the three piers on the third or upper floor, which are in the same north and south line, were occupied; the central pier, of stone, with marble top, was used for declination and intensity observations, and the most southerly pier, of wood, for dip observations. In either case these latter piers are designated as *U*. The standards of observatory instruments were, for declination and horizontal intensity, Cooke mag-

netometer No. 7, and for dip, dip circle No. 160, with needles Nos. 1 and 2 by Dover. In connection with the results by this series it should be remarked that owing to the limited time at the disposal of the Department observer the observations are not as extensive as could be desired. The *C. I. W.* results given may be subject to slight future modification when the final intercomparisons of standard are made at Washington upon the return of the instruments. The provisional correction for dip circle 202 is for the mean of needles 1 and 2, —0.′4.

Results of Declination Comparisons at the Alibag Observatory.

(C. I. W. magnetometer 7)

Date	Local mean time From	Local mean time To	Declination obtained* C. I. W.	Declination obtained* Alibag	C. I. W. —A.	Remarks
1911	h m	h m	° ′	° ′	′	
Mar. 23	8 30	8 39	+0 55.5	+0 54.9	+0.6	C. I. W. at L, Alibag
	11 21	11 30	54.5	53.8	+0.7	mag'r at U
	12 56	13 05	53.1	52.4	+0.7	
	14 52	15 01	54.7	53.3	+1.4	
	15 51	16 00	54.7	54.4	+0.3	C. I. W. at U, Alibag
	17 45	17 54	55.5	54.2	+1.3	mag'r at L
Mar. 24	7 25	7 34	55.1	55.1	0.0	
	9 11	9 20	56.9	55.2	+1.7	

Mean value (C. I. W.—A.) = +0.′8; P. E. = ±0.′1.

*All values reduced to lower floor pier, L (L—U=—1.′8); U=upper floor pier.

Results of Horizontal Intensity Comparisons at the Alibag Observatory.

(C. I. W. magnetometer 7)

Date	Local mean time From	Local mean time To	Horizontal intensity* obtained C. I. W.	Horizontal intensity* obtained Alibag	C. I. W. —A.	Remarks
1911	h m	h m	γ	γ	γ	
Mar. 23	9 28	11 14	36833	36865	—32	C. I. W. at L; Alibag mag'r at U
	13 09	14 44	804	850	—46	
	16 06	17 39	806	844	—38	C. I. W. at U; Alibag mag'r at L
24	8 29	9 06	801	841	—40**	Values 24th weighted ½

Weighted mean value (C. I. W.—A.) = —38.9γ; P. E. = ±2.1γ.
or —0.00106*H*; P. E. = ±0.00006*H*.

*All values reduced to lower floor pier, L (L—U=+10.2γ); U=upper floor pier.

**Half set with Alibag magnetometer between 7h 39m and 8h 24m rejected because direct rays from the sun fell upon the instrument.

Results of Inclination Comparisons at the Alibag Observatory.

(C. I. W. dip circle Dover 202)

Date	Local mean time From	Local mean time To	D. C. 202 needle	Inclination obtained* C. I. W.	Inclination obtained* Alibag	C. I. W. —A.	Remarks
1911	h m	h m		° ′	° ′	′	
Mar. 22	12 31	13 19	1 & 2	+23 44.6	+23 44.4	+0.2	C. I. W. at L;
	13 25	14 11	1 & 2	44.0	45.6	—1.6	A. D. C. at U
	15 33	16 22	1 & 2	45.0	46.0	—1.0	C. I. W. at U; A.
	16 25	17 13	1 & 2	45.9	46.4	—0.5	D. C. at L
			Mean value (C. I. W.—A.)		=	—0.′7;	P. E. = ±0.′3.

*All values reduced to lower floor pier, L (L—U=+0.′6); U=upper floor pier.

The station differences used are as determined from the present series only. Professor Moos, Director, states that a long series of observations indicates difference in declination is —1.′4 and not appreciable in horizontal and vertical intensity.

Pilar Observatory.

During this series of intercomparisons, obtained by the officers of the *Carnegie*, four stations were used, viz., observatory stations 1 and 8 in the regular absolute house, and tent stations *B* and *C*, approximately east of the absolute house and in line with 1 and 8. The station 1 is the regular observatory pier for the absolute determination of declination and intensity, while station 8 is the regular observatory pier for the determination of dip. Station 8 is 9.02 meters east of the pier 1, station *B* is 33.04 meters east of station 8, and station *C* is 28.1 meters east of station *B*. The standard observatory instruments are: in declination and horizontal intensity, Kew magnetometer No. 138; in dip the mean of values as determined by earth inductor No. 3, constructed by Toepfer & Son, and the mean of needles 1 and 2, of Dover dip circle No. 216.

During the intercomparison work, the observer in charge of the observatory reports, there must have been present in the absolute house some local disturbance as his observations made prior and subsequent to the work of the officers of the *Carnegie* indicates that there is practically no station difference between the absolute house and stations *B* and *C*. It appears, however, from a consideration of the observations at *B* and *C* only that the differences of Pilar and the *C. I. W.* standards are within the error of observation practically the same as the results that are obtained by taking

account of all the intercomparisons made at the three stations. For this reason the latter values are adopted as apparently the temporary source of disturbance was in a fixed position during the intercomparison work.

The corrections of the *C. I. W.* instruments to its provisional International Magnetic Standards were: in declination, magnetometer 2, +0.′2, magnetometer 4, +0.′5; in horizontal intensity, magnetometer 2, —0.00030*H*, magnetometer 4, +0.00072*H;* in dip, earth inductor 2, —0.′5. The differences in values of corrections for the magnetometers over the values given in the first section of this article at the time of this work are due to some alterations and repairs made subsequently.

Results of Declination Comparisons at the Pilar Observatory, Argentina.

(C. I. W. magnetometers 2 and 4)

Date	Local mean time From	Local mean time To	Station C. I. W.	Station Pi.	Magneto-meter	Declination obtained* C. I. W.	Declination obtained* Pilar	C. I. W. −Pilar
1911	h m	h m				° ′	° ′	′
Jan. 28	9 49	9 58	C	1	2	+9 08.8	+9 07.4	+1.4
	9 49	9 58	B		4	08.4		+1.0
	12 03	12 12	C		2	12.2	11.3	+0.9
	12 04	12 13	B		4	12.4		+1.1
	14 17	14 23†	C		2	11.4	10.8	+0.6
	14 17	14 26	B		4	11.5		+0.7
	16 22	16 31	C		2	07.9	07.6	+0.3
	16 22	16 31	B		4	08.1		+0.5
30	9 06	9 15	1	B	2	06.2	05.3	+0.9
	9 05	9 14	C		4	05.8		+0.5
	11 12	11 21	1		2	11.1	10.3	+0.8
	11 12	11 21	C		4	10.7		+0.4
	14 30	14 39	1		2	14.3	13.1	+1.2
	14 31	14 40	C		4	13.3		+0.2
	16 30	16 39	1		2	10.5	09.7	+0.8
	16 31	16 40	C		4	10.0		+0.3
31	8 58	9 07	B	C	2	06.4	06.0	+0.4
	8 58	9 07	1		4	06.3		+0.3
	11 04	11 13	B		2	11.1	10.4	+0.7
	11 05	11 14	1		4	11.3		+0.9
	14 19	14 28	B		2	10.8	10.4	+0.4
	14 18	14 27	1		4	10.2		—0.2
	17 34	17 43	B		2	08.7	08.7	0.0
	17 33	17 42	1		4	08.4		—0.3

Mean value (C. I. W.—Pilar) = +0.′6; P. E. = ±0.′06.

*All values have been reduced to station B (B=Pier 1—0.′9; B=C+0.′4).

†⅔ set. Observer jarred tripod.

Results of Inclination Comparisons at the Pilar Observatory.
(C. I. W. earth inductor 2)

Date	Local mean time From	Local mean time To	Station C. I. W.	Station Pi.	Inclination obtained* C. I. W.	Inclination obtained* Pilar	C. I. W. —Pilar
1911	h m	h m			° ′	° ′	′
Feb. 1	13 43	14 09	B	8	—25 52.0	—25 52.3	+0.3
	14 16	15 26			52.6†	52.3	—0.3
	15 51	16 29			54.6	54.0	—0.6
2	9 19	9 46	C	B	53.3	52.7	—0.6
	10 43	11 11			52.5	(52.5)	0.0
	11 47	12 07			52.9	52.7	—0.2
	15 49	16 15	8	C	54.1	54.9	+0.8
	16 48	17 10			54.2	(54.5)	+0.3
	17 26	17 50			54.4	54.8	+0.4

Mean value (C. I. W.—Pilar) =0.′0;. P. E. = ±0.′1.

*All values are reduced to station B (B=Pier 8—2.′8; B=C+0′).

†Mean of two determinations. The values in parentheses are interpolated ones from preceding and following sets.

Results of Horizontal Intensity Comparisons at the Pilar Observatory.
(C. I. W. magnetometers 2 and 4)

Date	Local mean time From	Local mean time To	Station C. I. W.	Station Pi.	Magnetometer	Horizontal intensity obtained* C. I. W.	Horizontal intensity obtained* Pilar	C. I. W. —Pilar
1911	h m	h m				γ	γ	γ
Jan. 28	10 07	11 35	C	1	2	25656	25678	—22
	10 07	11 45	B		4	658		—20
	14 37	16 11	C		2	668	686	—18
	14 37	16 13	B		4	675		—11
30	9 28	11 02	1	B	2	673	697	—24†
	9 28	11 03	C		4	680		—17
	14 52	16 19	1		2	660	664	—04
	14 52	16 21	C		4	652		—12
31	9 23	10 54	B	C	2	688	708	—20
	9 23	10 56	1		4	686		—22
	16 00	17 25	B		2	646	665	—19
	15 59	17 28	1		4	641		—24

Weighted mean value (C. I. W.—Pilar) = —17.5γ; P. E. = ±1.2γ.
or —0.00068H; P. E. = ±.00005H.

*All values reduced to station B (B=Pier 1—29.8γ; B=C+3.4γ).

†Weight ½; half set rejected on account of observer's note as to darkness and difficulty in reading horizontal circle.

Samoa Observatory.

The observations reported upon of May, 1906, by the *Galilee* party were made on the regular pier of the Observatory in the old absolute house. The Samoa data given are taken from the volume of results for 1905 to 1908[12]. It appears that at this time there was for magnetic inclination at the point of observation some local disturbance, which, according to information received from Dr. Angenheister of the Observatory staff was such as to reduce numerically negative values of dip by about four minutes of arc; the values of dip circle 171 have been corrected accordingly. Several other stations were occupied within the Observatory enclosure during May, 1906, but unfortunately there was no interchange of stations to determine station differences as it was reported that there was no local disturbance in the immediate neighborhood of the Observatory; subsequent examination has shown that the distribution is not uniform, and it is, therefore, not possible to utilize all the observations for intercomparisons. The difference in declination determined below is further confirmed indirectly by the comparisons of magnetometers 36 and Tesdorpf 2025 at Suva Vou, Fiji, on May 20, 1906, the values at the same station at different times being reduced to mean of day by the diurnal variation results obtained at Apia; the resulting difference (*C. I. W.*-2025) is —0.′4. From the observations made with 2025 at the absolute house during December, 1905, January, March, and December, 1906, the mean difference (*Samoa*-2025) was found to be —0.′2. Hence (*C. I. W.*-*S.*) would be from this indirect comparison —0.′6, which is in good agreement with the value directly observed in May, 1906. The horizontal intensity results by 2025 in 1905 and 1906 at Apia had necessarily to be used for the determination of constants so that no indirect check can be made from them on the intensity difference.

The *Galilee* party on the third cruise during March, 1907, again made observations at several stations without an interchange of stations within the Observatory enclosure, but could not occupy the absolute station, as at this time the old absolute house was being replaced by a new one. In addition to the unsuspected local disturbance as at the first visit in May, 1906, there seems to have been at this time other disturbances due to the building operations.

The standards of the Samoa Observatory are those of the Potsdam Observatory, and it will be noted that the agreement of the

[12]Ergebnisse der Arbeiten des Samoa-Observatoriums der königlichen Gesellschaft der Wissenschaften zu Göttingen. V. Der erdmagnetischen Registrierungen der Jahre 1905 bis 1908. Von F. Linke und G. Angenheister.

differences on the provisional International Magnetic Standards of the Department is very good.

Results of Declination Comparisons at the Samoa Observatory (Apia).

(Magnetometer U. S. C. & G. S. 36)

Date	Local mean time		Declination obtained		C. I. W.—S.
	From	To	C. I. W.	Samoa	
1906	h m	h m	° ′	° ′	
May 3	8 29	8 38	+9 36.7	+9 37.4	—0.7
	10 28	10 37	36.3	36.5	—0.2

Mean value (C. I. W.—S.) = —0.′4; P. E. = ±0.′2.

Results of Horizontal Intensity Comparisons at the Samoa Observatory (Apia).

(Magnetometer U. S. C. & G. S. 36)

Date	Local mean time		Horizontal intensity obta'ed		C. I. W.—S.
	From	To	C. I. W.	Samoa	
1906	h m	h m	γ	γ	γ
May 3	8 42	9 29	35692	35681	+11
	9 34	10 18	707	685	+21

Mean value (C. I. W.—S.) = +16.0γ; P. E. = ±3.3γ.
or +0.00045H; P. E. = ± 0.00009H.

Results of Inclination Comparisons at the Samoa Observatory (Apia).

(C. I. W. dip circle Dover 171 for series I and II)

Series	Date	Local mean time		Needles used	Inclination obtained		C. I. W. —S.	Remarks
		From	To		C. I. W.	Samoa		
	1906	h m	h m		° ′	° ′	′	
I	May 3	16 43	17 21	I & 2	—29 15.7	—29 14.5	—1.2	
	4	7 50	8 35	I & 2	13.5	14.1	+0.6	
	8	8 59	10 00	I & 2	12.2	(13.3)	+1.1	Weight ½
							0.0	P. E. = ±0.′5
II	Dec. 8	13 17	16 04	5 & 6	—29 21.8	—29 21.1	—0.7	
	9	9 53	10 37	of 172	19.6	20.4	+0.8	
	10	11 14	12 03	" "	17.8	18.2	+0.4	
	13	10 22	11 07	" "	17.8	17.3	—0.5	
							0.0	P. E. = ±0.′2

Weighted value (C. I. W.-S.) from I and II = 0.′0; P.E. = ±0.′2

Christchurch Observatory.

The work of the Christchurch Observatory was carried out at the absolute house and several stations in the Observatory enclosure. A careful examination made by the Observatory authorities over the enclosure showed that no measurable station differences existed. The standards are a Kew magnetometer and a Dover dip circle.

Results of Declination Comparisons at the Christchurch Observatory.
(Magnetometers 2025 for series I and C. I. W. 4 for series II)

Series	Date	Local mean time From	Local mean time To	Declination obtained* C. I. W.	Declination obtained* Christchurch	C. I. W. —C.	Remarks
	1906	h m	h m	° ′	° ′	′	
I	July 9	11 09	11 27	+16 27.3	+16 25.6	+1.7	2025 at east pier
		12 15	12 32	28.1	27.9	+0.2	absolute observa-
		14 17	14 33	31.4	30.8	+0.6	tory
	21	10 23	10 46	28.3	27.2	+1.1	
						+0.9	P. E. = ±0.′22
	1907						
II	Dec. 31	11 15	11 24	+16 33.4	+16 32.1	+1.3	Tent
		13 00	13 09	38.9	37.4	+1.5	"
		15 29	15 38	37.5	36.3	+1.2	Absolute house
		17 21	17 30	34.0	32.7	+1.3	" "
	1908						
	Jan. 3	15 13	15 22	38.1	36.8	+1.3	Absolute house
		17 04	17 13	35.7	34.4	+1.3	" "
	4	11 16	11 25	34.9	33.9	+1.0	Tent
		12 51	13 00	40.3	38.9	+1.4	"
	6	15 35	15 44	40.9	39.6	+1.3	Absolute house
						+1.3	P. E. = ±0.′03

Mean value (C. I. W.—C.) from series I and II = +1.′3; P. E. = ±0.′03.

*There is no appreciable station difference.

Results of Horizontal Intensity Comparisons at the Christchurch Observatory.
(C. I. W. magnetometer 4)

Date	Local mean time From	Local mean time To	Horizontal intensity* obtained C. I. W.	Horizontal intensity* obtained Ch'stch'ch	C. I. W. —C.	Remarks
1907	h m	h m	γ	γ	γ	
Dec. 31	11 41	12 38	22578	22559	+19	Tent
	16 07	17 10	618	601	+17	Absolute house
1908						
Jan. 3	15 40	16 46	624	611	+13	Absolute house
4	11 37	12 21	599	575	+24	Tent
	14 42	15 28	631	610	+21	"
6	15 58	16 54	615	602	+13	Absolute house

Mean value (C. I. W.—C.) = +17.8γ; P. E. = ±1.2γ.
or +.00079*H*; P. E. = ±0.00005*H*.

*There is no appreciable station difference.

Results of Inclination Comparisons at the Christchurch Observatory.

(C. I. W. dip circles Dover 171 for series I, and 169, 178, and 189 for series II)

Series	Date	Local mean time From	Local mean time To	C. I. W. circle and needles	Inclination obtained* C. I. W.	Inclination obtained* Christchurch	C. I. W. —C.	Remarks
	1906	h m	h m		° ′	° ′	′	
I	July 10	9 16	10 24	171–1 & 2	—67 48.0	—67 46.8	—1.2	171 at W
		11 24	12 26	171–1 & 2	48.0	47.8	—0.2	
		14 46	15 49	171–1 & 2	50.0	47.3	—2.7	
	July 11	9 42	11 16	171–1 & 2	—67 48.4	—67 47.7	—0.7	171 at B
		14 45	15 50	171–5 & 6	48.1	47.8	—0.3	Needles 5 &
	12	10 10	11 20	171–5 & 6	49.3	48.9	—0.4	6 are of
		14 24	15 22	171–5 & 6	50.8	49.5	—1.3	dip circle
	16	11 43	12 42	171–1 & 2	50.5	48.5	—2.0	Dover 172
	Mean value (C. I. W.—C.) from I = —1.′1; P. E. = ±0.′2.							
	1907							
II	Dec. 30	15 33	16 25	178–1 & 2	—67 50.7	—67 49.1	—1.6	See note*
	31	10 15	11 32	169–1 & 2	52.9	51.8	—1.1	
		11 33	11 59	169–1 & 2	52.2	51.4	—0.8	
		14 51	15 33	169–1 & 2	51.2	48.8	—2.4	
		15 54	16 54	169–1 & 2	50.8	48.8	—2.0	
	1908							
	Jan. 3	11 41	13 04	189–5 & 6	51.9	50.0	—1.9	
		14 30	15 46	189–5 & 6	50.8	48.2	—2.6	
		15 54	17 01	189–5 & 6	49.7	48.2	—1.5	
		17 31	17 58	178–1 & 2	52.0	49.0	—3.0	
	6	12 23	12 48	178–1 & 2	50.7	50.1	—0.6	
	Mean value (C. I. W.—C.) from II = —1.′8; P. E. = ±0.′2.							
	Weighted mean value (C. I. W.—C.) from I and II = —1.′4; P. E. = ±0.′1.							

*There is no appreciable station difference between West pier absolute house, W, and peg II B; in series II observations were made at 3 different points in the observatory inclosure not designated.

Indirect Intercomparisons of Observatory Standards.

By means of the recent work of Dubinsky[14] and Kühl[15] it is possible to determine also indirectly the difference on the Department's provisional international magnetic standards at Pavlovsk, Katharinenburg, Irkutsk, Upsala, Rude Skov, De Bilt, and Val Joyeux. These indirect comparisons are also of great interest because of the conception given by them of the high relative accuracy

[14] DUBINSKY, W.—Bericht über die Versammlungen des Internationalen Meteorologischen Komitees und dessen Kommission für Erdmagnetismus und Luftelektrizität. *Veröff. met. Inst.*, No. 227, Berlin, 1911 (88).

[15] KÜHL, W.—Vergleichung der Hauptbarometer und der magnetische absoluten Instrumente in de Bilt, Paris—Val Joyeux und Pavlovsk mit denen in Berlin—Potsdam. Berlin, *Veröff. met. Inst.*, No. 229, 1911 (150-159).

of results attainable with entirely different types of instruments and independently determined constants.

Designating the observatories by the following abbreviations: Pavlovsk = *Pav.*, Katharinenburg = *Ka.*, Irkutsk = *I.*, Upsala = *U.*, Rude Skov = *R. S.*, De Bilt = *De B.*, Val Joyeux = *V. J.*, Potsdam = *P.*, Kew = *K.*, Tiflis = *T.*, we have the following results: (*Pav.-K.*) = —8.6 γ = —0.00046*H*, per Dubinsky in October, 1908; (*Pav.-P.*) = —6.7 γ = —0.00036*H*, per Dubinsky in November, 1908; (*Pav.-T.*) = 0.0 γ = 0.00000*H*, per Dubinsky in December, 1907. Adopting the differences obtained by the Department at Kew, Potsdam, and Tiflis, there result the following values: (*C. I. W.-Pav.*) = +0.00053*H*, +0.00060*H*, and +0.00043*H*, respectively. Owing to the outstanding question as to whether there was not some local artificial disturbance at Tiflis during the observations by the Department the determination from the Tiflis work is rejected and the difference (*C. I. W.-Pav.*) adopted as +0.00056*H*. From this value the following differences result in connection with the differences on Pavlovsk as given by Dubinsky: (*C. I. W.-Ka.*) = +0.0005*H*; (*C. I. W.-I.*) = +0.0005*H*; (*C. I. W.-U.*) = 0.0000*H* (the instrument at Upsala being the large theodolite by Lamont), and (*C. I. W.-R. S.*) = +0.0011*H*. From the provisional values as published by Kühl in connection with the difference (*C. I. W.-P.*) = +0.00024*H*, we obtain the following: (*C. I. W.-De B.*) = —0.0000*H*, and (*C. I. W.-V. J.*) = —0.0008*H* in June, 1910.

In declination we have from Dubinsky: (*Pav.-K.*) = +0.′7 in October, 1908, and (*Pav.-P.*) = +0.′2 in November, 1908, while per Kühl, (*Pav.-P.*) = +0.′2 in July, 1910; whence, using the differences of the Department standards on the observatories Kew and Potsdam we obtain values of (*C. I. W.-Pav.*) = +0.′0, +0.′1, and +0.′1, respectively, the mean value being +0.′1. The difference (*Pav.-R. S.*) at Rude Skov is, according to Dubinsky's observation in September, 1908, +0.′2; hence (*C. I. W.-R. S.*) = +0.′3. From Kühl's observations in 1910, and using the difference (*C. I. W.-P.*) = +0.′3, we have the following, (*C. I. W.-De B.*) = +0.′6, and (*C. I. W.-V. J.*) = +0.′8, in June, 1910.

In inclination the showing is equally good. From Dubinsky's work we have: (*Pav.-K.*) = —0.′9 in October, 1908, (*Pav.-P.*) = +0.′7 in November, 1908; and from Kühl, (*Pav.-P.*) = +0.′4 in July, 1910; whence, using the differences as determined by the Department on its standards for the observatories Kew and Potsdam

we have the difference (*C. I. W.-Pav.*) = —0.′8, —1.′0, and —0.′7, respectively, the difference being in the mean —0.′8. Dubinsky's comparisons at the Tiflis Observatory in November and December, 1907, give: (*Pav.-T.*) = +0.′4, whence (*C. I. W.-T.*) should be —0.′4 instead of —1.′6 as per the direct observations made by the Department during 1908, in which it is suspected that there was local artificial disturbance present. In view of the excellent agreement at the observatories the difference as determined indirectly from the Pavlovsk comparisons is accepted for the time being. From the results reported by Dubinsky during June, 1908, to November, 1908, and using the above difference (*C. I. W.-Pav.*) = —0.′8, the following differences result: (*C. I. W.-Ka.*) = —0.′3, (*C. I. W.-I.*) = —1.′8; (*C. I. W.-U.*) = —1.′0 (the standard at Upsala being Dover dip circle 60 and needles 3 and 4), and (*C. I. W.-R. S.*) = —1.′3. For these four comparisons except at Upsala, the standards are earth inductors. From the observations reported on by Kühl we have in June, 1910, the following from the use of the difference of the observatory at Potsdam as determined by the Department on its standard: (*C. I. W.-De. B*) = —1.′5 (the standard instrument at De Bilt being Dover dip circle 61): (*C. I. W.-V. J.*) = +1.′5 (the observatory standard being dip circle), or (*C. I. W.-V. J.*) = —0.′5 (the observatory standard being earth inductor Schulze No. 61).

It should be noted in connection with the observations by Kühl that the results given are entirely provisional and may be subject to modification. His observations in 1910 at Pavlovsk in horizontal intensity seem to give an anomalous value of the difference between the Potsdam and Pavlovsk standards, and for this reason his determination at this point has not been used, pending further revision.

Summary of Results of Observatory Intercomparisons.

The results of the comparisons are summarized in Table III; the values given are to be applied algebraically, east declination, north inclination, and horizontal intensity being reckoned as positive, and west declination and south inclination being reckoned as negative. The *declination determinations* indicate generally that the provisional standard adopted by the Department is probably from 3-10 to 5-10 minute too high for east declination. Account being taken of the limit of accuracy possible in the astronomical determi-

Table III.

Summary of Results of Observatory Intercomparisons.

No.	Difference	Declination Mean Δ D	Declination P. E. Δ D	Inclination Mean Δ I	Inclination P. E. Δ I	Horizontal intensity Mean Δ H	Horizontal intensity P. E. Δ H	Dates and Remarks
		′	′	′	′			
2	C. I. W.—Potsdam	+0.3	±0.0	−0.3	±0.1	+0.0002H	±0.00005H	Feb., 1910.
3	C. I. W.—Kew	+0.7	±0.1	−1.7	±0.2	+0.0001H	±0.00003H	Mar., 1908, Mar., 1910.
5	C. I. W.—Pola	−0.3	±0.1	+0.1	±0.1	+0.0005H	±0.00003H	Feb., 1910.
6	C. I. W.—Toronto	−0.5	±0.1	+0.8[a]	±0.1	+0.0002H[b]	±0.00004H	Sep. and Oct., 1906, by Dept. Oct. to Nov., 1909, and Apr. Sep., and Oct., 1910, by Meteorological Service.
7	C. I. W.—Tiflis	+0.7	.....	−1.6[c]	±0.1	+0.0004H[c]	±0.00004H	June, 1908.[d]
10	C. I. W.—[e] Cheltenham	+0.2	±0.0	+0.1	±0.1	−0.0008H	±0.00003H	Feb. and Mar., 1908, and Mar., 1910.
11	C. I. W.—Zi-ka-wei	−1.0	±0.1	−1.1	±0.3	+0.0006H	±0.00003H	May and Sept., 1907.
12	C. I. W.—Dehra Dun	+0.2	±0.1	−0.1	±0.3	+0.0016H[f]	±0.00005H	Oct., 1909.
13	C. I. W.—Helwan	+0.5	±0.1	+0.2	±0.1	+0.0003H	±0.00006H	Apr., 1908.
14	C. I. W.—Havana	+0.9	±0.2	+1.6	±0.5	.....	.....	May, 1905.
15	C. I. W.—Hongkong	+0.6	±0.3	−1.2	±0.2	+0.0022H[g]	±0.00006H	Dec., 1908, for D and H, and March, 1911, for I.
17	C. I. W.—Alibag	+0.8	±0.1	−0.7	±0.3	−0.0011H	±0.00006H	Mar., 1911.
19	C. I. W.—Samoa	−0.4	±0.2	0.0	±0.2	+0.0004H	±0.00009H	May, 1906, for D and H, and May and Dec., 1906, for I.
20	C. I. W.—Pilar	+0.6	±0.1	0.0	±0.1	−0.0007H	±0.00005H	Jan. to Feb., 1911.
22	C. I. W.—Melbourne	.....	.....	−0.3	±0.3	.....	.....	Nov., 1906.

TABLE *III.*—*Continued.*

Summary of Results of Observatory Intercomparisons.

No.	Difference	Declination Mean Δ D	Declination P. E. Δ D	Inclination Mean Δ I	Inclination P. E. Δ I	Horizontal intensity Mean Δ H	Horizontal intensity P. E. Δ H	Dates and Remarks
23	C. I. W.—Christch'ch	+1.3	±0.0	—1.4	±0.1	+0.0008*H*	±0.00005*H*	July, 1906, and Dec. 1907, to Jan., 1908, in D and I; Dec., 1907, to Jan., 1908, for H.
	Indirect observatory intercomparison results.[h]							
	C. I. W.—Upsala	.....	.....	—1.0	.....	0.0000*H*	.....	Sept., 1908.
	C. I. W.—Pavlovsk	+0.1	.....	—0.8	.....	+0.0006*H*	.....	Oct. and Nov., 1908, and July, 1910, for D and I; Oct. and Nov., 1908, for H.
	C. I. W.—Katharinenburg	.....	.....	—0.3	.....	+0.0005*H*	.....	June, 1908.
	C. I. W.—Rude Skov	+0.3	.....	—1.3	.....	+0.0011*H*	.....	Sept., 1908.
	C. I. W.—Irkutsk	.....	.....	—1.8	.....	+0.0005*H*	.....	June to July, 1908.
	C. I. W.—de Bilt	+0.6	.....	—1.5	.....	—0.0000*H*	.....	June, 1910.
	C. I. W.—Val Joyeux	+0.8	.....	+1.5[i]	.....	—0.0008*H*	.....	June, 1910.
	C. I. W.—Tiflis	.....	.....	—0.4	.....	+0.0006*H*	.....	Dec., 1907.

(a) This difference in I at Toronto is as based on the old observatory standard, viz., Dover circle 130, needles 1 and 2, since superseded by Dover circle 200, needles 1 and 2, for which the Department has as yet no data.

(b) This difference in H at Toronto is as based on the new observatory standard, Elliott magnetometer 98, and constants adopted in February, 1911; see page 79 for various particulars regarding differences on older standards.

(c) See page 139 regarding possible local artificial disturbance during this work. Compare the results obtained for Tiflis with the indirect comparison of December, 1907.

(d) The observatory results for the comparisons of June and July, 1909, are not yet available.

(e) The standards for the United States Coast and Geodetic Survey observatories at Sitka, Baldwin, Honolulu, and Vieques, are identical with those at Cheltenham. The same remark applies for the new observatory at Tucson, which succeeded the Baldwin Observatory, discontinued in October, 1909.

(f) This is on the basis of the value of $\pi^2 k$ of September, 1909, for the observatory standard magnetometer; see other remarks, page 144.

(g) Referred to magnetometer 83 at Hongkong ΔH would be +0.0008H; see page 148.

(h) Determined from reports of intercomparisons of Dubinsky and Kühl and Department observations at Kew and Potsdam.

(i) The difference in inclination for observatory earth inductor, Schulze 61, is —0.'5.

nations for azimuth and position with a readily portable type of instrument, such as can be used in magnetic survey work, and of the errors due to reductions for diurnal variation, it appears that so far as magnetic declination is concerned the present types of instrument give an accuracy of the highest order that may be asked. The *dip circle results*, account being taken of the wide range covered, are certainly very satisfactory; it appears that the provisional standard in dip from a consideration of all results is probably from 3-10 to 5-10 minute too low for northerly dip. The results of the intercomparisons serve to emphasize the fact that the suitable adaptation of the earth inductor for field use is desirable, as offering very much less difficulty in the correlation and reductions of the various instruments, and at the same time that a greater accuracy may be obtained with dip circles than has been generally thought possible. The *horizontal intensity determinations* indicate that the provisional international magnetic standard may be as much as $0.0001H$ to $0.0002H$ too high, although this is well within the error of field results. The probable errors of the results would indicate that having once determined the constants of the instruments and corrections on the basis of such constants obtained to standard, an absolute accuracy in the field of 1-5000th part of the value of the horizontal intensity may be reached by careful work, even in cases where the instruments are in severe field service of periods of two or three years; the uncertainties involved in reducing for diurnal variation are of this order or greater, although they may be considerably reduced by suitably selecting the time for observation.

The interest taken in the question of intercomparison of magnetic standards has been particularly emphasized by the eagerness and readiness with which the directors and officials of the various observatories have extended the facilities and assistance of their respective institutions, and for which grateful acknowledgment is made. The observatory results have also been usually furnished quite promptly and with great detail and care. The interest taken also indicates the enthusiasm with which magnetic survey work is at present everywhere being carried on.

Department Terrestrial Magnetism,
Carnegie Institution of Washington.
July 31, 1911.

DATA FOR ABRUPTLY BEGINNING MAGNETIC DISTURBANCES, 1906-1909, No. II

Reports from Batavia-Buitenzorg; Zi-ka-wei and Lu-kia-pang; Kew; Mauritius; Eskdalemuir; Dehra Dun, Kodaikanal, Barrackpore, and Toungoo; Tortosa; Samoa; Falmouth; De Bilt; Rude Skov; Pilar; and additional data for Potsdam; Agincourt; Porto Rico, Cheltenham, Baldwin, Sitka, and Honolulu.

KONINKLIJK MAGNETISCH EN METEOROLOGISCH OBSERVATORIUM TE BATAVIA, 6 FEBRUAR, 1911.

Replying to your request of December 20, 1910, I have the pleasure to send copies of our magnetic diagrams for the 15 magnetic disturbances. The following information will enable you to determine the moments and variations you want.

The time written on the sheets of the Adie magnetograph is mean civil time of Batavia (longitude = $7^h\ 07^m\ 19^s$); that on the sheets of the Töpfer-Schulze magnetograph Greenwich mean civil time. The time corresponding to the time-mark (which is made by the assistant) is given to the nearest minute. The error of the chronometer used for the time-mark may be accepted never to have exceeded 0.1 minute.

For the Adie magnetograph the following rules hold: When the curves approach the base-line, horizontal intensity, H, and easterly declination, D, increase, and vertical intensity, Z (upward), decreases. When the temperature increases the curves for H and Z move away from the base-line and their thermograph lines approach it.

For the Töpfer-Schulze magnetograph: When the curves for the intensity components, X, Y, and Z move away from the base-line their values increase. When the temperature increases the temperature curves for X and Y approach the base-line and that for Z moves away. However in the beginning of 1908, Z was reversed and accordingly it behaved in 1908 and 1909 contrarily to the rule given above.

For the disturbances 1 to 4 are at my disposition high speed registers at Batavia made for the purpose of registration of earth-currents. On these sheets the time-marks are quite exact, being made electrically by an assistant every hour from the standard clock. The error thus will not have exceeded 0.5 second. The light-beam being eclipsed all the curves show the hourly marks.

The results are exhibited in the following table and accompanying figure.

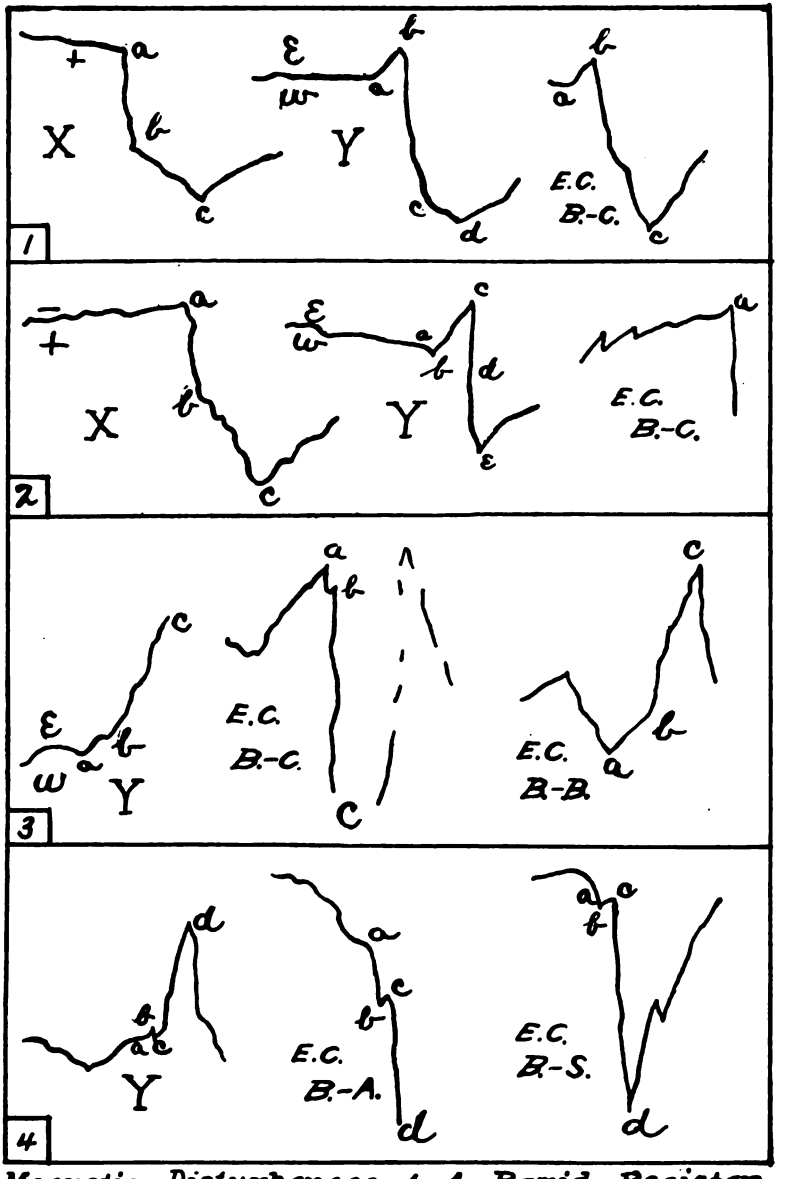
No	Date	Comp't	Scale value		Time of point marked	Magnitude of deflection	Earth current notes		
			Time	Inte'ity			Remarks	Time of point	Magnitude
	1906		m	γ	h m	γ		h m	mm
1	July 29	X	0.960	0.42	a 19 56.43		Batavia=	a 19 56.12	
					b 19 58.59	ab 23.5	Cheribon	b 19 56.33	ab 1.0
					c 20 00.28	ac 27.4	E 18° S	c 19 58.85	ac 106.8
		Y		0.18	a 19 56.15		200 km		
					b 19 56.74	ab 0.72			
					c 19 58.59	ac 7.0			
					d 19 59.11	ad 7.7			
2	Aug. 7	X	0.960	0.42	a 13 38.35		Batavia	a 13 38.25	
					b 13 40.75	ab 7.6	-Cheribon		
					c 13 49.30	ac 11.8			
		Y		0.18	a 13 37.91				
					b 13 39.16	ab 0.31			
					c 13 40.02	ac 0.45			
					d 13 40.75	ad 0.00			
					e 13 42.80	ae 1.26			
3	Dec 21	Y	0.957	0.3	a 21 27.85		Batavia-	a 21 28.81	
					b 21 29.29	ab 0.5	Cheribon	b 21 29.48	ab 2.3
					c ?	ac ?		c ?	ac >85
							Batavia-	a 21 28.91	
							Buitenzorg	b 21 30.25	ab 3.0
							S5° E46km	c 21 33.88	ac 80.5
	1907								
4	Feb. 9	Y	0.962	0.324	a 14 13.45		Batavia-	a 14 13.35	
					b 14 13.74	ab 0.97	Anjer	b 14 13.55	ab 4.5
					c 14 13.83	ac 0.00	W6°N	c 14 13.64	ac 1.5
					d 14 17.11	ad 12.64	106 km	d ?	ad ?
							Batavia-	a 14 13.25	
							Semarang	b 14 13.35	ab 2.0
							E 12° S	c 14 13.55	ac 0.0
							406 km	d 14 14.12	ad 131.0

Scale values.

Disturbance No.	Adie Magnetograph					Töpfer-Schulze Magnetograph					
	H	thH	Z	thZ	D	X	thX	Y	thY	Z	thZ
	γ	γ	γ	γ	′	γ *	γ	γ	γ	γ	γ
1, 2	3.53	2.98	10.9	0.75	1.116	2.30 —0.0066 (150-S)	1.21	2.52	0.16	5.5	0.04
3	"	"	"	"	"	"	"	2.58	"	13?	"
4	3.51	"	11.1	"	"	2.16 —0.0062 (150-S)	"	2.60	"	9?	"
5	"	"	"	"	"	2.30 —0.0070 (150-S)	"	"	"	13?	"
6	"	"	"	"	"	"	"	"	"	11?	"
7	3.52	"	11.	"	"	"	"	2.79	"	12?	"
8	"	"	14.	"	"	2.14 —0.0064 (150-S)	"	"	"	—	—
9, 10	"	"	6.7	"	"	"	"	"	"	—	—
11, 12	"	"	6.7	"	"	"	"	"	"	—	—
13	3.54	"	?	—	"	2.38 —0.0077 (150-S)	"	2.77	"	4.9	0.36
14, 15	"	"	?	—	"	"	"	3.08	"	5.1	"

*S denotes measured ordinate from base-line in millimeters.

W. VAN BEMMELEN.



Magnetic Disturbances 1-4 Rapid Register
Batavia - Buitenzorg

Note on Time Scalings of the Buitenzorg Magnetograms.—The time scalings of the Buitenzorg magnetograms of certain suddenly beginning magnetic storms in 1906-1909,[1] given in the accompanying tabulation, were made by the direct method,[2] which in detail is as follows:

In the accompanying illustration the line A B is the base-line of the magnetogram, *X*, *Y*, and *Z* are the curves of the magnetic elements, *g*, *h*, and *k* are the points of the abruptly beginning disturbance, the time of which is to be scaled from the magnetogram; *a*, *m*, *n*, and *o* are the points of beginning of the mechanical interruption of base-line and of the *X*, *Y*, *Z* curves, these points being simultaneous as to time of occurrence, the time of occurrence of the time break *a*, being recorded in terms of the standard chronometer (or clock) whose error on local mean time is known.

The broken lines, *m n*, *n c*, and *o b* are portions of perpendicular lines from the points *m*, *n*, *o*, and are of such lengths that *d* and *g*, *c* and *h*, and *b* and *k* are respectively of equal perpendicular distance from the base-line *A B*; that is, a line from *d* to *g* would be parallel to the base-line, and so with *c h* and *b k*. This construction is easily performed with a pair of dividers, and in the case of the Buitenzorg curves here considered the perpendiculars were drawn with the aid of the C. & G. Survey reading board.[3] Having the points *d*, *c*, and *o* thus fixed, the distances *d g*, *c h*, and *b k* are then taken off with a beam compass (or millimeter scale) and laid off on the base-line *A B* from the point *a*; thus, the distance *d g* corresponding to the distance *a p*. The distance from *p* to the nearest preceding hour break is then read off with a millimeter scale and converted into minutes (having regard also to the actual length, in millimeters, of the hour interval upon which the point fell) and applied to the correct local time of the hour break. This result is then converted into Greenwich mean civil time by the application of the difference in longitude in time.

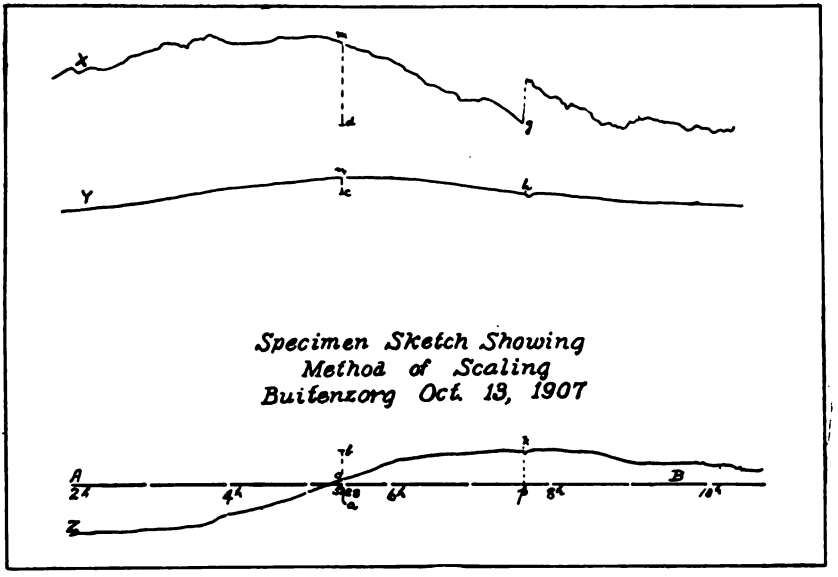
In this method the lengths of the portions of the perpendiculars used is so short that any error in constructing the perpendicular will not affect the result. The effect of shrinkage of the paper does not affect the result, as it is known the shrinkage of paper is practically uniform for any given direction. The shrinkage for the fractional hour is practically zero.

[1] *Terr. Mag.*, v. 15, No. 2, p. 101.

[2] *Terr. Mag.*, v. 16, No. 2, pp. 111, 112.

[3] For description of this reading board see p. 7 "Results of Observations made at the Coast and Geodetic Survey Magnetic Observatory at Cheltenham, Maryland, 1901-04," by D. L. Hazard, Wash. Govt. Printing Office, 1909.

In the case of the Biutenzorg curves the time written on the Toepfer-Schulze magnetograms was mean civil time of Greenwich, and on the Adie magnetograms was Batavia mean civil time, the latter readings are given in the tabulations in Greenwich time, the difference of longitude ($7^h\ 7^m\ 19^s$) having been applied to times as scaled from the magnetograms. As the times stated on the sheets for the time-marks (the mechanical interruptions of the traces) are given to the nearest minute only, the times given in the tabulations are correspondingly affected.

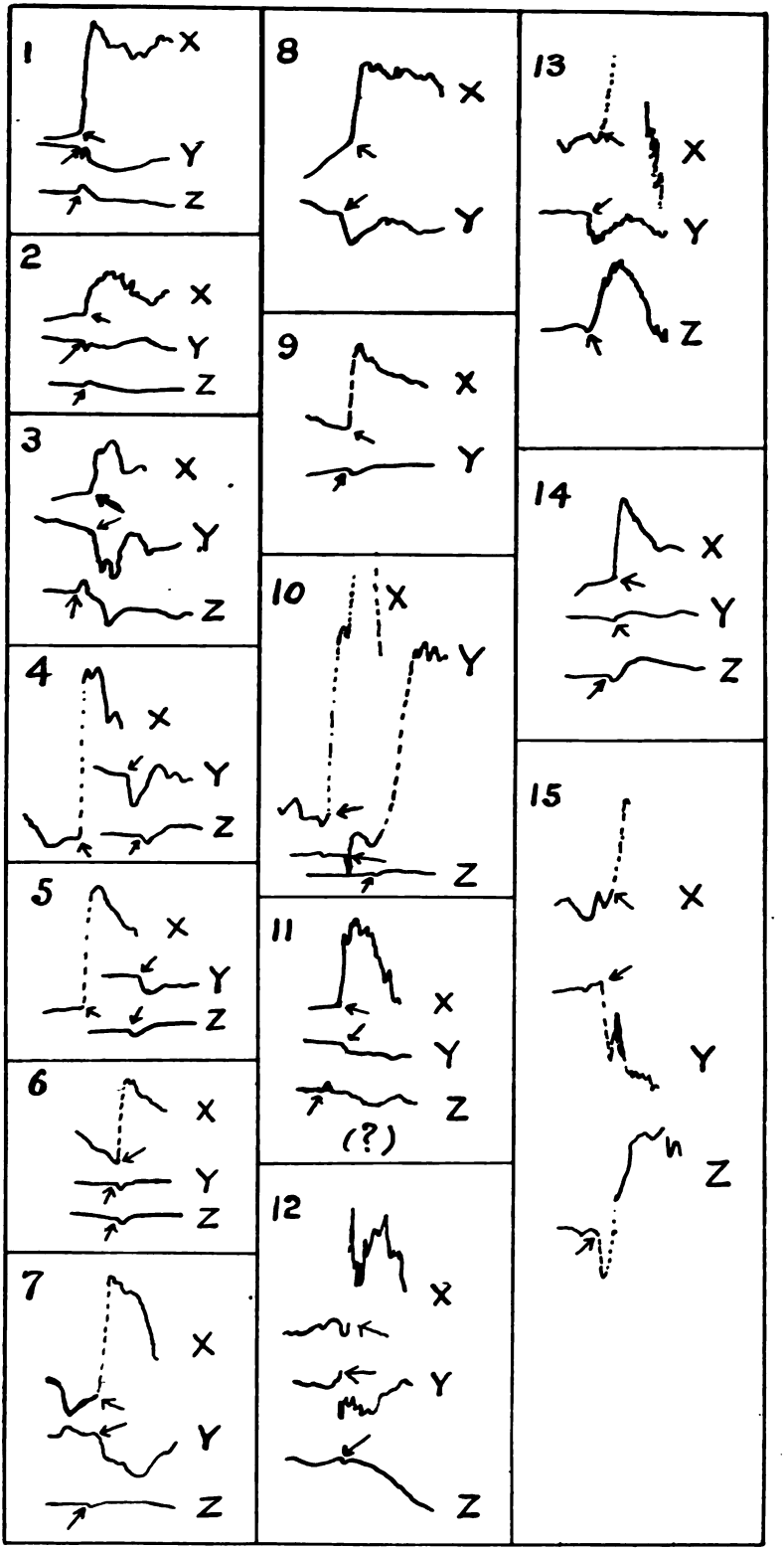


The duration of the "first deflection" was ascertained by constructing a perpendicular to the base-line from the first turning-point of the curves, and then measuring the interval from the point of beginning of the sudden disturbance to this perpendicular in a direction parallel to the base-line. This interval in millimeters was then converted into minutes of time.

In the tabulation a plus (+) for the magnitude of the "first deflection" means increasing X, Y, and Z (or decreasing Z in northern magnetic hemisphere).

In deciding upon the exact point of beginning of the sudden disturbance the diagram of the Potsdam magnetic curves, published in *Terrestrial Magnetism*, v. 16, No. 2, p. 93, was examined in each case in order to identify the corresponding feature of the curve, but such identification was not certain in a number of instances.

R. L. FARIS.



Buitenzorg Magnetic Disturbances 1906-09.

Greenwich Mean Civil Times of Sudden Beginnings of Magnetic Storms 1906-09 at Buitenzorg, measured by R. L. Faris.

No.	Date	Component	Time of beginning	First Deflection: Duration in minutes	First Deflection: Magnitude in mm	First Deflection: Magnitude in γ	Remarks
	1906		h m				
		X	19 56.1	3.9	+15.3	+35	
1	July 29	Y	56.1	1.0	— 1.2	—30	
		Z	56.1	1.8	+ 0.6	+ 3	
		X	13 36.3	2.4	+ 3.7	+ 9	
2	August 7	Y	36.3	1.8	— 0.5	— 1	
		Z	36.9	1.8	+ 0.4	+ 2	
		X	21 30.0	3.0	+ 5.8	+13	
3	Dec. 21	Y	30.6	3.0	— 1.6	— 4	
		Z	30.6	1.8	+ 4.2	+57(?)	
	1907	X	14 12.0	4.0	+22.0	+48	
4	Feb. 9	Y	12.0	2.1	— 4.0	—10	
		Z	12.9	1.5	— 0.6	— 5(?)	
		X	14 23.1	4.0	+16.2	+37	
5	July 10	Y	22.8	3.3	— 2.1	— 5	
		Z	24.0	2.0	— 0.6	— 8(?)	
		X	7 40.8	4.0	+11.0	+25	
6	Oct. 13	Y	41.7	0.3	— 0.6	— 2	
		Z	42.6	2.5	— 0.5	— 6(?)	
	1908	X	17 38.4	3.6	+16.2	+37	
7	March 26	Y	39.0	3.9	— 3.6	—10	
		Z	38.7	3.0	+ 0.4	+ 5(?)	
		X	0 14.7	4.2	+10.3	+22	
8	August 19	Y	15.0	4.2	— 4.0	—11	
		Z	....	...	.....	....	
		X	7 18.9	3.6	+11.9	+25	
9	Sept. 11	Y	17.7	2.7	— 0.6	— 2	
		Z	....	...	....	....	
		X	21 47.1	4.5	+24.8	+53	
10	Sept. 11	Y	45.9	0.6	— 2.0	— 6	
		Z	43.8	1.5	+ 0.2	+ (?)	
		X	8 42.6	2.4	+10.0	+21	Traces are marked Sept. 29th.
11	Sept. 28	Y	(?) 42.0	3.3	— 1.1	— 3	
		Z	42.2	1.5	— 1.0	— 7	Adie Z curve.
		X	1 34.8	3.0	+16.7	+36	
12	Sept. 29	Y	33.6	2.4	— 7.0	—20	
		Z	31.2	2.4	+ 0.3	+ 2	Adie Z curve.
	1909	X	4 55.2	(?)	+ (?)	(?)	
13	May 14	Y	56.4	3.0	— 3.0	— 8	
		Z	57.0	4.5	— 8.0	—54(?)	Adie Z curve.
		X	8 38.7	4.5	+10.3	+25	
14	Sept. 25	Y	39.3	6.0	+ 1.0	+ 3	
		Z	39.3	2.4	+ 0.5	+ 3	
		X	11 42.6	(?)	+ (?)	(?)	
15	Sept. 25	Y	42.0	2.1	—10.0	—31	
		Z	42.6	1.2	+ 7.0	+36	

OBSERVATOIRE MAGNÉTIQUE MÉTÉOROLOGIQUE ET SISMOLOGIQUE, ZI-KA-WEI ET LU-KIA-PANG, PRÉS CHANG-HAI, CHINE, 11 FEVRIER, 1911

We furnish to scale the fifteen curves concerning which Dr. Bauer wrote asking information. The traces during 1906 and 1907 were made at Zi-ka-wei. Here two astronomical clocks by Fénon, Nos. 65 and 39, are used, the latter of which shows local time and the former zone time (China coast time). For the traces 39 was used, the time breaks being made as follows: On each day, about 9. A. M., a good watch was compared roughly with 39, the observer then going to the magnetograph room and placing a paper before the three cylinders, leaving it long enough to interrupt the trace, between one and two minutes, the mean time of the interruption being noted. The time scalings were made by reference to the daily mark and an error of one-half minute is quite possible and probable. An interval, however, of a minute will hardly make a perceptible mark on the trace. The marks on the three curves may be considered as strictly simultaneous. In the comparisons of the deflections for the three elements the smaller sensitiveness of the Lloyd balance for the vertical intensity should be borne in mind, and for this reason also the times indicated for the disturbance in the vertical intensity may be less exact than those for the other two elements.

In March, 1908, the instruments were transferred to Lu-kia-pang, where we began to use zone time. We have no clock at this point but use a chronometer made by Müller, No. 3931. Every day, about 10 A. M., Sundays and a few feast days being excepted, an observer at Zi-ka-wei compares a deck watch with one of the clocks and gives the clock time according to his deck watch by telephoning to the Lu-kia-pang observer, who compares with No. 3931. It has not yet been found worth while to correct 3931 or to change the oil; it is now more than an hour fast. As the observers are not always the same the rate of 3931 is, when possible, calculated from the comparisons made by the same men; the records show some small changes in rate but on the whole the chronometer is satisfactory. The time breaks are made at Lu-kia-pang on the photographic traces as they were at Zi-ka-wei, the observer's private watch being previously compared with chronometer 3931. The observers do not concern themselves with seconds, so that the time breaks may be in error by half a minute or so, and sometimes more. By using 3931 at 9 A. M. the obsrvers must use the correction of chronometer of the previous

day, but the difference would be at most not more than one or two seconds.

The traces have been scaled independently by two men, viz., Messrs. Lou and Zi. They first noted the Greenwich time of the nearest hour (local time at Zi-ka-wei, zone time at Lu-kia-pang) and then measured the distance from that hour to the sudden change. The ordinates in declination were measured with special rules graduated in minutes of arc according to the respective scale values at Lu-kia-pang and Zi-ka-wei. In horizontal intensity and total intensity the ordinates were measured in millimeters and reduced to gammas by means of the scale values.

J. DE MOIDREY, S. J.

Data for Greenwich Mean Times of Magnetic Disturbances at Zi-ka-wei and Lu-kia-pang.

No.	Date	Element	G. M. T. of beginning of disturbance	G. M. T. of next sudden change	Deflection	No.	Date	Element	G. M. T. of beginning of disturbance	G. M. T. of next sudden change	Deflection
	1906		h m	h m			1908		h m	h m	
1	Jul 29	D	19 54	20 06	0.′7 W	9	Sep 11	D	7 19	7 24	0.′4 E
		H	54	19 59	+24γ			H	19	21	+22γ
		Z	54	58	— 2γ			Z	No trace	.....	.....
2	Aug 7	D	13 41	13 43	0.′5 E	10	Sep 11	D	21 46	21 56	3.′6 W
		H	37	40	+12γ			H	45	54	+93γ
		Z	39	42	— 1γ			Z	No trace	.....	.....
3	Dec 21	D	21 35	21 37	0.′5 E	11	Sep 28	D	Poor trace	.....	.....
		H	30	40	+63γ			H	8 39	8 40	+16γ
		Z	Nothing	.....	.....			Z	42	44	— 3γ
	1907										
4	Feb 9	D	14 11	14 22	1.′6 E	12	Sep 29	D	1 31	1 36	1.′3 E
		H	11	13	+34γ			H	33	34	+34γ
		Z	09	11	—10γ			Z	32	34	— 6γ
							1909				
5	Jul 10	D	14 22	14 23	0.′4 E	13	May 14	D	4 57	5 17	3.′3 E
		H	22	29	+34γ			H	54	07	+68γ
		Z	Not clear	.....	.....			Z	54	4 58	— 7γ
6	Oct 13	D	7 46	7 47	0.′2 E	14	Sep 25	D	8 38	8 44	1.′1 E
		H	44	49	+20γ			H	37	41	+21γ
		Z	46	48	— 3γ			Z	38	40	— 2γ
	1908										
7	Mar 26	...	No trace	.....	.....	15	Sep 25	D	11 38	11 53	10.′5 E
								H	40	44	+143γ
8	Aug 19	D	Poor trace	.....	.....			Z	39	41	— 26γ
		H	0 15	0 20	+19γ						
		Z	No trace	.....	.....						

KEW OBSERVATORY, RICHMOND SURREY, FEBRUARY 25 AND MARCH 29, 1911.

In response to the request which you addressed some time ago to the Meteorological Office our curves have been examined on the occasions of the 15 magnetic disturbances given on your revised list. The results of the measurements of times and amplitudes are given in the accompanying sheets. Measurements were made in all cases both by Mr. Baker and myself and allowance made so far as possible for any error in measuring scale or times shown by the curve. Please remember that we do not claim accuracy to nearer than 1 minute as a rule. In one case I have put down a ½ minute, but only as indicating that the difference in time between two very near points seemed under a minute. I have given in each instance a rough sketch of the *D* (declination) and *H* (horizontal force) curves. In a good many cases the curves were not quiet at the time, and the first point recorded was in several instances probably in advance of the movement which you really want. One might have for instance (see disturbance No. 1, *H* curve, or No. 4, *D* curve) a somewhat rounded top and then a somewhat more rapid dip down indicated by *A* and *B*, followed by a considerably sharper upper movement *B C*. In such a case the chances are that what you really want is the time of *B*. In such cases I have given the times of both *A* and *B*. The sketch and verbal description will, I hope, enable you to decide what you really want.

Again, in rather a number of cases, there were several oscillations. The amplitudes of several have been measured in such cases, as it is impossible to foresee what comparison of amplitudes you may desire to make. I suspect in such cases you will find the identification of corresponding movements at different stations difficult. I must say that a large proportion of the cases do not seem to me ideal for the purpose aimed at. If one can get a single sharp movement at a quiet time, identification presents less difficulty.

Our vertical force traces are very sensibly disturbed and useless for exact time determinations. Even measurements of amplitude are very uncertain, quite too uncertain in the case of rapid oscillatory movements. When there is a single well-defined movement, as indicated above, a *rough* estimate of amplitude is possible. But the *V* measurements sent you should be regarded only as gener-

ally indicative of the amplitude. For purposes of calculation you may take for the values of the elements here:

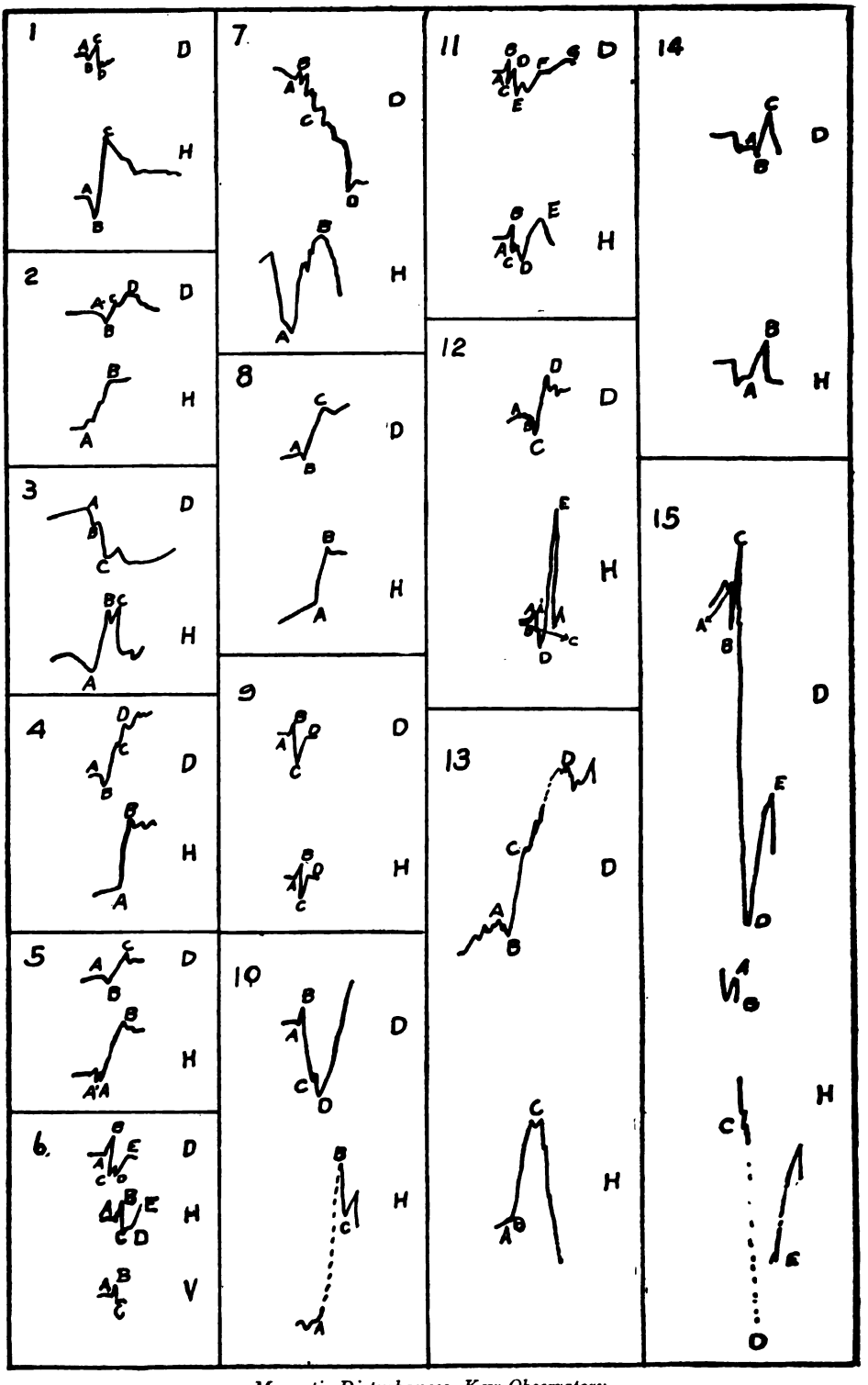
	1906	1909
D	16° 28′ W	16° 11′ W
I	67° 02′ N	67° 00′ N
H	0.1852 C. G. S.	0.1851 C. G. S.
V	0.4371 " " "	0.4359 " " "

Even our *D* and *H* curves are not free from tram influence, causing the edge of the trace to be by no means sharp, and at times there are movements which one may mistake for natural disturbances. Thus the conditions are less favorable than they were for exact time determinations 12 years ago or even in 1902–3. The times are all Greenwich Mean Civil Time.

In our traces up the sheet means: increasing westerly declination, and increase of both force elements, *H* and *V*. As to the method, the measuring scale was not quite correct (i. e., ordinates and abscissae not strictly perpendicular), the error at 10 centimeter ordinate being 1.6 minutes. This required a correction to the time as deduced by measurement of the curves at the rate of —1.6 minutes per 10 centimeters of ordinate. The times of starting and stopping by the clock being say $10^h\ 17^m$ and $10^h\ 15^m$, and the curve ordinates 58 and 62mm., the times deduced by actual measurement with the scale were $10^h\ 18^m$ and $10^h\ 16^m$. The scale corrections being —0.9 and —1.0 minutes, the corrected times are accepted as $10^h\ 17^m$ and $10^h\ 15^m$, thus agreeing with the clock times. At the time of the disturbance the ordinate is say 55 mm., so that going as we did to the nearest minute, simply one minute was deducted from the time as shown by the scale. So far as I can remember there was no case in which the ordinates at starting, stopping, or commencement of disturbance differed enough to require a different correction. The magnetograph clock is checked by a chronometer whose error is really known to one second, but the clock (one drives all the drums) has no seconds hand.

The times given relate to the successive letters shown in the figures on page 174, except where otherwise indicated by letters immediately following the times. The drawings are not exact copies, being merely intended to illustrate general features.

CHARLES CHREE,
Superintendent



Magnetic Disturbances, Kew Observatory.

Greenwich Mean Civil Times of Sudden Beginnings of Magnetic Storms, 1906-1909, at the Kew Observatory.

No.	Date	Element	Times	Remarks
	1906		h m	
1	July 29	D	19 56.5	AB not clear (might be tram) perhaps 0.′3.
			19 57	BC about 0.′7.
			19 58	CD about 1.′0.
			20 00	
		H	19 57	AB very rapid = 8γ.
			19 58	BC = 57γ.
			19 59	
		V	.....	Rise of about 10γ in course of 3 or 4 minutes from commencement.
2	Aug. 7	D	13 39A	Corner A not very sharp. AB = 0.′4.
			13 41B	Angle B sharp. BD = 1.′7.
			13 46D	Movement delays at C about 1 minute.
		H	13 39	Curve (which had not been very quiet) began
			13 46	to rise pretty sharply at A going to B, stopping momentarily twice by the way, AB = 22γ.
		V	.....	Rise of about 5γ in five minutes, then return.
3	Dec. 21	D	21 33	Rounded top, highest point somewhere about
			21 35	21h28m. At A a fairly marked decline, which
			21 44	hangs a little at B. AB about 1′, AC about 4.′3
		H	21 31	Force, which had been falling, suddenly went
			21 35	up from A to B; but motion slower for first
			21 39	minute than later. AB = 35γ.
		V	.....	Vertical force trace lost.
	1907			
4	Feb. 9	D	14 12	Prior to sudden decline at A curve nearly level
			14 13	but not free from small oscillations. Slight
			14 14	hang at C, and further rise some time after
			14 16	D. AB = 0.′4; BC = 3.′3; BD = 5.′2.
		H	14 13	H had been rising gradually, rose suddenly at A.
			14 15	AB = 42γ.
		V	.....	Rise in V of about 10γ in 2 or 3 minutes.
5	July 10	D	14 22	Decl'n had been fairly quiet up to A, fall AB
			14 24	= 0.′3 not very rapid.
			14 28	BC = 2.′6. Summit at C a little rounded.
		H	14 22	Slight and indistinct burr on the H curve from
			14 24	A′ to A might be artificial. Rise AB more
			14 28	rapid at first than later. AB = 41γ.
		V	.....	Moving up at the time; any temporary disturbance effect small.
6	Oct. 13	D	7 43	Complicated movement. Rise AB and fall BC very rapid.
			7 44	AB = 1.′6, BC = 3.′7, DE = 1.′7.
			7 45	
			7 47	
			7 53	
		H	7 43	H movement also complex. Rise AB and fall BC very rapid.
			7 44	AB = 10γ, BC = 14γ, DE = 13γ.
			7 45	
			7 49	
			7 54	
		V	.....	AB = 2γ; BC = 6γ. Curve at this time almost free from tram disturbance.

Greenwich Mean Civil Times of Sudden Beginnings of Magnetic Storms, 1906-1909, at the Kew Observatory.—Continued.

No.	Date	Element	Times	Remarks
	1908		h m	
7	March 26	D	17 43	Complicated movement. At A there is the
			17 44	first of several small oscillations at a time
			17 52	when decl'n was falling. There is a short
			18 20	delay at C more marked than elsewhere. The ending movement down just before D is sharp. AB = 0.′3; BC = 4.′0; BD = 13′.
		H	17 43	In case of H a fall of about 50γ ended at A.
			17 55	Initial rise rapid, broken by small oscillations before crest B reached. AB = 53γ.
		V	.....	V rose about 20γ while rise of 53γ in H was going on.
8	Aug. 19	D	00 15	Small decline at A following gradual rise.
			00 16	AB =0.′4; BC = 5.′2.
			00 20	
		H	00 15	In H rapid rise commenced at A, after a much
			00 20	more gradual rise. AB = 38γ.
		V	.....	V rose about 6γ during above rise in H.
9	Sept. 11	D	7 19	In decl'n sudden small rise at A, followed by
			7 20	fall BC and partial return.
	Forenoon		7 23	AB = 0.′6; BC = 3.′7; CD = 1.′7.
			7 26	
		H	7 18	In H sudden small rise at A, followed by fall
			7 19	BC and recovery CD.
			7 22	AB = 8γ; BC = 19γ; CD = 11γ.
			7 25	
		V	.....	Movement small, if existent; hidden by artificial disturbances.
10	Sept. 11	D	21 47	Upward decl'n movement at A *may* be preceded
			21 49	by very small sudden downward movement.
	Afternooon		21 54	The downward movement from B to C was
			21 59	most rapid at first; it shows some tiny oscillations about C. AB = 1.′0; BC = 8′½ very rough; BD = 13.′0.
		H	21 47	The H trace, which had been considerably dis-
			21 49	turbed and was at the time moving upwards
			21 54	fairly rapidly, received a suddenly accelerated upward motion at A. Rise to B very rapid. AB = 112γ. Fall BC = 52γ less rapid.
		V	.....	V results too uncertain.
11	Sept. 28	D	8 41	Decl'n very complex movement.
			8 42	AB = 0.′9; BC = 2.′3; CD = 1.′5; DE = 3.′0;
			8 43	EF = 3.′2; EG = 5.′1.
			8 44	
			8 48	
			8 57	
			9 08	
		H	8 41A	H had sharp small rise AB, the fall BD was
			8 42B	slightly interrupted at C.
			8 45D	AB = 7γ; BD = 28γ; ED = 33γ.
			8 56E	
		V	.....	V movement not large if existent.

Greenwich Mean Civil Times of Sudden Beginnings of Magnetic Storms, 1906-1909, at the Kew Observatory.—Continued.

No.	Date	Element	Times	Remarks
	1908		h m	
12	Sept. 29	D	1 29	A little crest at A was followed by a short,
			1 33	not very rapid fall AB, and then a rapid fall
			1 34	BC, and larger rapid rise CD.
			1 37	AB = 0.′6; BC = 1.′7; CD = 7.′8.
		H	1 29	H movement confused. At A during fairly
			1 30	quiet time there is a faint indication of a
			1 31	small oscillation AA′B (which if real was
			1 32	rapid). After B was a small delay BC; then
			1 33	a small, very rapid dive CD and a much
			1 37	larger very rapid rise DE, followed by a closely similar fall. AA′ = 3γ (very uncertain); A′B = 8γ (very uncertain); CD = 9γ; DE = 75γ.
		V	.....	V too uncertain.
	1909			
13	May 14	D	4 54	Decl'n was oscillating. At A commenced a
			4 56	downward movement, possibly interrupted
			5 03	by small oscillation. At B upward much
			5 24	more rapid movement commenced. The rate was nearly uniform up to C; then more slow with minor oscillations. AB = 1.′4; BC = 13.′9; BD = 26.′3.
		H	4 57	At A horizontal force showed an upward move-
			4 58	ment rapid from the start, but more rapid
			5 03	after B. There may have been a small oscillation just before A. The curve was then not quite quiet. AB = 3γ; AC = 72γ.
		V	.....	V rose about 10γ during the big rise in H.
14	Sept. 25	D	8 38	The D curve had not been quiet. At A there
			8 39	is a small sharp downward movement fol-
	Forenoon		8 42	lowed by pretty rapid rise. AB = 0.′4; BC = 4.′0.
		H	8 38	The H trace had not been quiet; a pretty rapid
			8 40	downward movement had ended about 8^h 35^m. At A there was a pretty rapid upward movement AB followed by similar downward movement. AB = 20γ.
		V	.....	V too uncertain.
15	Sept. 25	D	11 42A	The declination trace had for some time shown
			11 43B	many small oscillations. The up and down
	Near Noon		11 45C	movement AB, BC, is so rapid that the sep-
			11 55D	aration of the up and down strokes is not
			11 56D	really clear, and not unlikely the movement
			12 04E	was larger than shown. The sweep down from C to D, though very rapid, was interrupted by several momentary pauses or small oscillations. The trace was off the sheet at D for a minute or so, so swing not quite complete. AB = 7.′4; BC = 11.′3; CD = 76′.

Greenwich Mean Civil Times of Sudden Beginnings of Magnetic Storms, 1906-1909, at the Kew Observatory.—Continued.

No.	Date	Element	Times	Remarks
			h m	
15	Sept. 25	H	11 41	The H curve had been in rapid oscillation.
			11 42	During a fairly rapid movement down from
	Near Noon		11 46	a small peak A, trace suddenly becomes in-
			11 51	visible at B, indicating a very rapid move-
			12 01	ment. After a little it becomes visible again, traveling down the sheet. Near C motion sensibly slower, probably small oscillations. Trace off the sheet at D and next seen some ten minutes later at E. AB = 17γ; BC = 190γ approx.; BD = 420γ.
		V	....	V rose apparently (but trace very faint and uncertain) about 55γ, and then fell about 110γ, all in two minutes or rather less. This oscillation seems to answer to the first very rapid oscillation in D. At 11:50 V was about 90γ less than when disturbance began.

THE ROYAL ALFRED OBSERVATORY, PORT LOUIS, MAURITIUS, FEBRUARY 28, 1911.

In reply to your letter of December 20, 1910, I have the pleasure to forward herewith particulars of the magnetic disturbances enumerated by Mr. R. L. Faris, in *Terrestrial Magnetism*, volume 15, page 101.

T. F. Claxton,
Director.

The times given below are obtained by means of a diagonal scale, showing intervals of 10 minutes for varying values of the time scale, which is normally about 125 mm. for 2 hours.

The clock is always kept within 0.5 m of true time, and the action of the light-shutter is controlled by recording the times at which the lamps are extinguished for cleaning on each day. Any correction necessary is made by placing the zero of the diagonal scale the correct amount to the right or left of the beginning of the hour-break, according as the light-shutter acts before or after the hour. The error seldom exceeds one minute.

The measured times may be considered correct to the nearest minute, as a rule; but errors of one minute may occasionally occur.

It may be mentioned that if the light be cut off for, say, 10 minutes, and the resulting white interval be measured, it will be found to amount to only 5 or 7 minutes, according to the intensity of the light. Any error from this effect, however, is eliminated by using the recorded times of extinguishing the lamp for obtaining the zero of the time scale.

Royal Alfred Observatory, Mauritius. Magnetic Disturbances with Sudden Beginnings for the Period 1906–1909.

Date	Beginning of Sharp Movement			End of Sharp Movement			Amount of Movement			Remarks
	H. F.	V. F.	Dec.	H. F.	V. F.	Dec.	H.F.	V.F.	Dec.	
1906	h m	h m	h m	h m	h m	h m	γ	γ	′	
July 29	19 56	19 56	19 56	19 57	19 58	19 57	+22	— 9	—0.5	
Aug. 7	13 40	13 46	13 40	13 46	13 47	13 46	+ 7	— 1	+0.4	H.F. & Dec. Register not sharp.
Dec. 21	21 29	21 28	.....	21 32	21 30	.....	+49	—13	.....	No movement in Dec.
1907										
Feb. 9	14 21	14 21	14 21	14 23	14 23	14 23	+ 9	— 3	+1.5	
July 10	14 32	.....	14 34	14 40	.....	14 36	+17	....	+0.7	No V.F. Register
Oct. 13	7 49	.....	7 54	7 55	.....	7 56	+17	....	—1.0	" " "
1908										
Mch 26	16 38*	.....	.....	16 47	.....	.....	+11	....	.....	V.F. & Dec. Register faint.
	17 48†	.....	.....	17 56	.....	.....	+18	....	.....	" "
Aug. 19	0 20	0 20	0 30	0 24	0 24	0 40	+14	— 2	—0.8	Dec. time uncertain, but no movement before $0^h\ 30^m$.
Sept. 11	7 29	7 29	7 34	7 34	7 34	7 35	+16	— 2	—0.8	
Sept. 11	21 58	21 56	21 57	22 00	21 57	22 5	+60	—14	—1.0	
Sept. 28	8 54	.....	.....	8 55	.....	.....	+ 8	....	.....	No sudden movement in V. F. or Dec.
Sept. 29	1 40	1 40	1 42	1 42	1 41	1 43	+23	— 6	—13	
1909										
May 14	5 5	5 3	5 5	5 13	5 9	5 6	+42	— 7	+0.6	Movement in Dec. until $5^h\ 10^m$, but not sharp.
Sept. 25	Times uncertain till after 9^h.									
Sept. 25	11 50	11 48	11 51	11 52	11 49	11 52	+47	—50	—3.0	

*Actual beginning of disturbance.
†A second sharp movement.

THE OBSERVATORY, ESKDALEMUIR, LANGHOLM, DUMFRIESSHIRE, MARCH 2, 1911.

(Transmitted through DR. W. N. SHAW, Director of the Meteorological Office.)

I am sorry that our contribution must be small. The Adie recorders only started in December, 1909, and before July, 1909, we had no knowledge of our absolute time. All I have of a reliable nature is the Eschenhagen record for September 25, 1909, and I send you the analysis of this. The geographical position is latitude 55° 19′ N, longitude 3° 12′ W.

1909. September 25th. The time scale is 1 mm. = 3 minutes and the times are readings directly by mm. scale.

Element	Time	Corr. to r. h. side of dot	Corr. Time	1st Turning Pt.	Time	Corr. to center of dot	Corr. Time
	h m		h m		h m		h
D	8 33	—3 m	8 30	1.'5 to E.	8 35	—2 m	8 33
H	8 32	—2 m	8 30	—20γ	8 35	—2 m	8 33
V	8 31	0 m	8 31	+1γ	8 34	0 m	8 34
D	11 45	—3 m	11 42	56′ to E	12 00	—2 m	11 58
H	11 43.5	—2 m	11 41.5	—440γ	11 55	—2 m	11 53
V	11 42.5	0 m	11 42.5	+148γ	12 00	0	12 00

The clock correction was nil and the times are estimated to be correct to ½ min. + or —.

Absolute times are controlled by a daily telegraphic time signal from Greenwich.

GEORGE W. WALKER,
Superintendent.

SURVEY OF INDIA, OFFICE OF No. 18 PARTY (MAGNETIC), DEHRA DUN, MARCH 2, 1911.

(Transmitted through J. ECCLES, M. A., Superintendent Trigonometrical Surveys).

I am sending you a list of sudden beginnings of the Magnetic disturbances in compliance with your circular request dated 20th December, 1910. I hope this will be useful to you.

In finding out the mean times all known errors have been allowed for as best as they could possibly be ascertained as will be seen from the annexed specimen calculation. Our scale for measuring the time ordinate is divided to 10 ms, one minute being equal to .01 of an inch; the scale is therefore not wide enough to read accurately to more than one minute; 2 or 3 readings have invariably been taken, to find the time of each disturbance and these were all within one minute. There are, however, sources of error such as identification of the starting point of a disturbance, the unequal expansion and contraction of paper, etc., which can not be allowed for. As regards your paragraph 2, I am sorry I am unable to send you the disturbance effect at present as I have other urgent work in hand; I shall, however, be glad to supply these later on.

Specimen Computations. Scale Readings: 1^h 45.5^m, 1^h 44.8^m, 1^h 45.0^m; mean scale reading, 1^h 45.1^m. Correction for overlap $+5.0^m$; for clock $+0.1^m$; for hour cut off $+0.\ 2^m$; to G. M. T., -5^h 53.4^m. Reduced time, 19^h 57.0^m.

N. R. MAZUMDAR,
E. A. Superintendent.

Greenwich Mean Civil Times of Sudden Beginnings of Magnetic Storms 1906–09.

No.	Date	Element	Dehra Dun	Kodaikanal	Barrackpore	Toungoo
	1906		h m	h m	h m	h m
1	July 29	D	19 57·7	19	19	19 57·9
		H	56·9	57·8	57·0	57·3
		Z	....	....	....	....
2	Aug. 7	D	13 38·0	13	13	13 37·9
		H	37·9	37·9	37·7	37·8
		Z	37·3	....	....	....
3	Dec. 21	D	21 32·1	21	21 31·2	21 31·4
		H	31·5	31·1	31·3	30·1
		Z	....	....	....	....
	1907					
4	Feb. 9	D	14 15·0	14	.. ....	14 ....
		H	14·2	14·8	....	13·7
		Z	13·5	....	....	....
5	July 10	D	14 22·2	14	14 24·1	14 22·8
		H	22·4	24·7	23·4	24·5
		Z	22·9	24·9	23·0	21·7
6	Oct. 13	D	7 42·0	7 42·5	7	7 43·6
		H	43·6	43·1	42·9	42·9
		Z	42·8	43·6	41·8	41·6
	1908					
7	March 26	D	17 41·4	17	17	17 ....
		H	40·9	41·5	41·5	41·0
		Z	42·0	41·7	....	....
8	Aug. 19	D	0 14·3	0	0 14·3	.. ....
		H	14·4	14·4	14·1	....
		Z	14·5	....	12·3	....
9	Sept. 11	D	7 21·3	7	7	.. ....
		H	22·8	23·2	....	....
		Z	22·8	22·7	21·7	....
10	Sept. 11	D	21 46·3	22	21 46·8	.. ....
		H	47·1	48·6	47·7	....
		Z	47·4	48·5	47·2	....
11	Sept. 28	D	8	8	8	.. ....
		H	42·2	42·2	41·3	....
		Z	....	42·9	43·0	....
12	Sept. 29	D	1 33·1	1	1 33·2	.. ....
		H	31·9	32·5	33·9	....
		Z	....	32·4	34·1	....
	1909					
13	May 14		.. ....	.. ....	.. ....	.. ....
14	Sept. 25	D	8	8	8	8 ....
		H	37·0	37·5	37·8	37·4
		Z	....	....	....	....
15	Sept. 25	D	11 41·7	11 40·8	11 40·1	11 ....
		H	40·5	41·9	40·2	40·2
		Z	....	40·4	42·7	41·6

OBSERVATORIO DEL EBRO, TORTOSA, 4 MARS, 1911.

Je vous envoie si joint la note que vous me demandez dans votre lettre du 15 Février. Vous trouverez seulement 11 perturbations; les quatre qui manquent ne pouvaient me fournir le temps avec l'exatitude désirée.

Afin que vous puissiez vous rendre compte de l'allure de nos perturbations, je vous remets une copie en grandeur naturelle des commencements. Pour la déclinaison 1 mm. de l'ordonnée est égal à 1'; pour la comp. *H* est environ égal à 5 γ et pour la comp. *Z* égale à 6 γ environ. La date et l'heure sont données sur chaque copie au ferro-prussiate.

RICH. CIRERA, S. J.
Director.

Commencements des quelques petrurbations magnètiques à l'Observatoire de l'Ebro-Tortosa.

Temps moyen civil de Greenwich.

Date	Elem. mag.	Temps	Remarq.*	Date	Elem. mag.	Temps	Remarq.*	Date	Elem. mag.	Temps	Remarq.*
		h m				h m				h m	
1906	D	21 31.4	(b)	1908	D	17 42.4	(c)	1908	D	1 33.6	(b)
Dec. 21	H			Mars 26	H	41.6	(c)	Sept. 29	H	33.0	(b)
	Z	32.0	(b)		Z	41.9	(c)		Z	34.7	(b)
								1909			
1907	D	14 15.2	(b)	Août 19	D	0 13.3	(b)		D	8 36.7	(b)
Fevr. 9	H	16.9	(b)		H	12.1	(b)	Sept. 25	H	37.1	(b)
	Z	16.6	(m)		Z	13.0	(b)		Z	37.0	(b)
	D	14 23.1	(b)		D	7 20.4	(n), (c)		D	11 39.2	(b)
Jul. 10	H	22.5	(b)	Sept. 11	H	19.7	(n), (c)	Sept. 25	H	41.2	(b)
	Z	22.8	(b)		Z	21.1	(n), (c)		Z	39.2	(b)
	D	7 42.8	(n)		D	21 47.0	(c)				
Oct. 13	H	40.4	(n)	Sept. 11	H	45.5	(c)				
	Z	42.1	(n)		Z	46.7	(c)				

*(b) La mesure a été faite en bonnes conditions.

(c) Les traits horaires ont été traces au crayon par comparaison avec d'autres jours; la trace photographique ayant manqué à cause de quelque dérangément dans le mécanisme enregistreur de l'heure. Le temps calculé est susceptible d'un erreur plus grande.

(m) Commencement mal défini.

(n) Dans ce cas on n'a pas mesurè la distance entre les traits horaires de 7h et 8h, qui contiennent le commencement de la perturbation; mais celle comprise entre 8h et 9h (perturbation du 13 Oct. 1907), et entre 6h et 7h (perturbation du 11 Sept. 1908).

N. B. Pour l'enregistrement de l'heure il y a une petite lampe électrique en relation avec le centre horaire de l'Observatoire.

Elle s' allume toutes les heures pendant quelques secondes et imprime un trait noire sur le papier sensible. L'espace parcouru en une heure par le papier est environ de 22 millimètres. La finesse des traits horaires et des courbes est satisfaisante; et il semble qu' ou peut obtenir l'heure avec une erreur pas supérieure à $0^m.3$. Pour plus de détails il faut consulter "Mémoires de l'Observatoire de l'Ebre-Num. 3—La Section Magnétique."

Pour le calcul de l'heure du commencement des perturbations ci-dessus, ou a mesuré en millimètres et dixièmes de millimètre: (1) la distance entre les deux traits horaires qui contiennent le commencement de la perturbation; (2) la distance entre ce commencement et le trait horaire immédiat. Avec ces données, et admettant que le cylindre, actionné par un appareil d' horlogerie, a eu un mouvement uniforme pendant ce court intervalle, on calcule par una simple proportion les minutes et dixièmes de minute du temps. Cette operation a été faite séparément pour chaque élément.

SAMOA-OBSERVATORIUM DER KGL. GESELLSCHAFT DER WISSENSCHAFTEN ZU GOETTINGEN, 7. MAERZ, 1911

Endlich kann ich Ihnen die gewünschten Daten für den Beginn der Störungen 1906-1908 senden. Für 1909 sind die Curven von Herrn Dr. Wegener zu bearbeiten; derselbe ist eben auf der Heimreise von Samoa begriffen und kann diese Daten für 1909 daher erst in vielleicht 2-3 Monaten senden.

Die gewünschten Daten haben wir, Herr Dr. Rohloff und ich, mit allergrösster Sorgfalt ausgemessen. Die Unterschiede unserer Messungen habe ich wenigstens für die *H. I.*, und *Z* angegeben. Es ist aber gut möglich, dass wir auch einmal dieselben Fehler gemacht haben. Einige Einflüsse sind nämlich nicht gut kontrollierbar, so die Aenderung der Parallaxe durch Schiefbrennen der Registrierlampe, Verzerrungen im Papier durch Entwickeln und Trocknen. Dann ist die Messung der Parallaxe selbst nicht sehr leicht, wenn die Basis-Linie und die Curve der Horizontal-Intensität z. B. weit von einander entfernt sind. Ein Drittel Millimeter ist eben sehr wenig, aber auf unserer Registrierung immer schon eine Minute. Auch sind die Einsätze auf unserer tropisch gelegenen Station zuweilen klein und nicht plötzlich genug um eine scharfe Ablesung zu erlauben. G. ANGENHEISTER.

Eintrittszeiten der magnetischen Störungen in den Jahren 1906, 7, 8 in Samoa.

No.	Datum	Magn. Element	Eintrittszeit des ersten Einsatzes	Eintrittszeit des ersten Umkehrpunktes	Grösse des ersten Ausschlags	Richtung des ersten Ausschlags
	1906		h m	h m		
1	Juli 29	D	19 57.1	.. ....	0.'3	—
		H	56.9	20 03.9	19.2γ	+
2	Aug. 7	D	13 39.6	.. ....	0.'1	+
		H	37.6	13 42.6	6.0γ	+
3	Dez. 21	D	21 27.5	.. ....	0.'5	—
		H	27.5	21 29.5	32.4γ	+
	1907					
4	Febr. 9	D	14 12.8	.. ....	0.'2	+
		H	12.8	14 14.0	19.2γ	+
5	Juli 10	D	14 21.7	.. ....	0.'6	+
		H	.. ....	.. ....	.. ....	..
		Z	14 25.1	14 27.2	4.5γ	+
6	Okt. 13	H	7 43.8	7 48.0	14.9γ	+
		Z	44.9	46.0	4.7γ	+
	1908					
7	März 26	D	17 42.0	.. ....	0.'8	+
		H	42.0	17 42.9	13.4γ	+
8	Aug. 19	D	0 14.0	.. ....	0.'5	+
		H	14.3	0 16.8	18.8γ	+
9	Sept. 11	D	.. ....	.. ....	0.'0	..
		H	7 20.6	7 22.7	15.1γ	+
		Z	24.3	26.9	2.9γ	+
10	Sept. 11	D	.. ....	.. ....	0.'0	..
		H	21 47.7	21 48.3	23.0γ	+
		Z	47.4	48.2	5.8γ	+
11	Sept. 28	D	.. ....	.. ....	0.'0	..
		H	8 41.3	8 47.5	19.6γ	+
		Z	43.5	44.9	3.0γ	+
12	Sept. 29	D	1 33.9	.. ....	0.'5	+
		H	31.6	1 32.6	25.3γ	+
		Z	31.5	32.6	4.0γ	+

Das Samoa Observatorium liegt 171°45'.9 W. L. 13°48'.4 S. B.

In Samoa ist die Horizontal-Intensität = 0.356
die Vertikal-Intensität = —0.200 (bezogen auf das Nordende der Nadel)
die Deklination = 9°40'E

Bei Angabe der Richtung bedeutet bei der Horizontal-Intensität + eine Zunahme der Kraft in der Horizontalebene. Skalenwert etwa 3γ.

Bei der Vertikal-Intensität bedeutet + eine Zunahme der Kraft, die das Nordende der Nadel nach unten treibt. (Da die Vertikal-Intensität in Samoa negativ ist, so bedeutet + eine Abnahme des absoluten Wertes von V. I.) Skalenwert wechselnd von 6γ—1.5γ.

Bei der Deklination bedeutet + eine Zunahme der östlichen Deklination. Skalenwert 1'. Die Registriergeschwindigkeit beträgt 2^{cm} pro Stunde.

Die Genauigkeit der Zeitbestimmung setzt sich zusammen aus der Genauigkeit mit der der Uhrstand bekannt ist, plus der Genauigkeit mit der die Ablesung erfolgt. Für die Ablesung kommt die Schärfe der Kurve und der Stundenmarke, die Parallaxe der Kurve in Betracht. Der Uhrstand ist in allen Fällen bis auf $\pm 0.15^{min}$ sicher, d. i. bis auf $\pm 0.05^{mm}$ auf der Registrierung (mit Ausnahme des 10. Juli 1907, wo der wahrscheinliche Fehler des Uhrstandes für H. I. etwa 1^{min} für Z etwa 0.6^{min} beträgt). Der wahrscheinliche Fehler des Uhrstandes wurde aus dem Gang der Uhr während der benachbarten Tage berechnet.

Die Ungenauigkeit der Ablesung ist nicht unerheblich, besonders die Parallaxe ist zuweilen sehr schwer zu bestimmen, ihre Grösse schwankt bis zu 2^{min}; oft ist auch der Einsatz der Bewegung nicht plötzlich und markant genug, besonders bei der Deklination, die sich stets erheblich ungenauer als die Horizontal-Intensität ablesen lässt.

Bei der Horizontal-Intensität schwankt die Ungenauigkeit der Ablesung bis zu etwa $0.75^{mm} = 2.25^{min}$ und ist bei verschiedenen Personen verschieden. So betrug die Differenz der Ablesung zwischen Dr. Angenheister und Dr. Rohloff für Horizontal-Intensität und Vertikal Intensität:

					min		
No.	1	für den	29. Juli	1906	0.7	für	H. I.
	2	" "	7. Aug.	"	0.4	"	"
	3	" "	21. Dez.	"	0.4	"	"
	4	" "	9. Febr.	1907	0.0	"	"
	5	" "	10. Juli	"	2.2	"	Z
	6	" "	13. Okt.	"	2.3	"	H
					0.6	"	Z
	7	" "	26. März	1908	0.0	"	H
	8	" "	19. Aug.	"	0.8	"	"
	9	" "	11. Sept.	"	1.2	"	"
	10	" "	11. Sept.	"	0.1	"	"
					0.5	"	Z
	11	" "	28. Sept.	"	0.2	"	H
					2.6	"	Z
	12	" "	29. Sept.	"	0.0	"	H
					0.0	"	Z

Die in der Tabelle angegebenen Zeiten sind die Mittelwerte aus beiden Ablesungen, aus der Ablesung von Dr. Angenheister und der von Dr. Rohloff. Die Differenzen zwischen beiden Ablesungen sind zuweilen sehr klein oder gar 0. Es darf daraus aber nicht gefolgert werden, dass der wahrscheinliche Fehler der Ablesung 0 ist, da beide Beobachter sehr leicht dieselben Fehler machen können.

Wahrscheinliche Fehler des Uhrstandes:

		min				
Für No.	1	± 0.1	für	H. I.		
	2	0.1	"	"		
	3	0.1	"	"		
	4	0.07	"	"	min	
	5	0.6	"	D	±1.0	für Z
	6	0.14	"	H	1.6	" "
	7	0.1	"	"	0.1	" "
	8	0.1	"	"	0.1	" "
	9	0.06	"	"	0.14	" "
	10	0.06	"	"	0.14	" "
	11	0.16	"	"	0.1	" "
	12	0.16	"	"	0.1	" "

THE OBSERVATORY. FALMOUTH, MARCH 13, 1911

In compliance with the request conveyed in your letter of 20th December last, addressed to the Secretary of the Royal Society, I have made measurements of the sudden beginnings of three elements of the magnetic storms enumerated from 1906 to 1909, and send them enclosed together with the scale values.

Edw. Kitto,
Superintendent.

Greenwich Mean Civil Times of Sudden Beginnings of Magnet Storms, 1906–1909. Falmouth Observatory.

No.	Date	Element	Time	Value	Direction	Duration
	1906		h m			m
1	July 29	D	19 58	AB = 0′.3	W	1.0
				BC = 1.1	E	3.0
	" "	H	19 57	AB = 1.4 mm.	—	1.0
				BC = 10.0 "	+	2.0
	" "	V	19 59	AB = 0.4 "	—	0.5
				BC = 1.5 "	+	1.5
2	August 7	D	13 39	AB = 0′.3	E	1.0
				BC = 2.1	W	6.0
	" "	H	13 38	AB = 3.8 mm.	+	10.0
	" "	V		No movement apparent		
3	Dec. 21	D	21 31	AB = 6′.3	E	16.0
	" "	H	21 34	AB = 6.7 mm.	+	3.0
	" "	V	21 35	AB = 0.8 "	+	2.5
	1907					
4	February 9	D	14 13	AB = 1′.3	E	1.0
				BC = 7.5	W	3.0
	" "	H	14 15	AB = 3.8 mm.	—	sudden
				BC = 11.1 "	+	1.0
	" "	V	14 14.5	AB = 1.6 "	+	0.5
5	July 10	D	14 22	AB = 0′.7	E	2.0
				BC = 3.0	W	4.0
	" "	H	14 24	AB = 4.0 mm.	+	1.0
	" "	V	14 28	AB = 0.5 "	+	
6	October 13	D	7 42	AB = 2′.0	W	0.5
				BC = 3.6	E	2.5
	" "	H	7 45	AB = 1.9 mm.	+	sudden
	" "	V	7 47.4	AB = 0.2 "	+	
	1908					
7	March 26	D	17 43	AB = 1′.5	W	0.4
				BC = 1.4	E	0.6
				CD = 1.5	W	0.4
	" "	H	17 44	AB = 6.7 mm.	+	3.0
	" "	V	17 47	AB = 3.6 "	+	10.0
8	August 19	D	0 15	AB = 0′.7	E	1.0
				BC = 4.9	W	3.0
	" "	H	0 15	AB = 7.4 mm.	+	3.5
	" "	V	0 17.5	AB = 0.9 "	+	
9	Sept. 11	D	7 21	AB = 1′.0	W	1.0
	" "	H	7 21.5	AB = 1.1 mm.	+	0.5
	" "	V	7 26	AB = 0.4 "	—	
10	Sept. 11	D	21 48	AB = 12′.0	E	12.0
	" "	H	21 45.5	AB = 19.7 mm.	+	5.0
	" "	V	21 46	AB = 2.8 "	+	2.0
11	Sept. 28	D	8 43	AB = 1′.0	W	
	" "	H	8 42	AB = 1.2 mm.	+	
	" "	V	8 47	AB = 0.5 "	—	3.0

Greenwich Mean Civil Times of Sudden Beginnings of Magnet Storms, 1906-1909, Falmouth Observatory.—Continued.

No.	Date	Element	Time	Value	Direction	Duration
			h m			m
12	Sept. 29	D	1 29	AB = 2′.5	E	3.0
				BC = 8.2	W	3.0
	" "	H	1 31	AB = 1.2 mm.	—	3.0
				BC = 11.7 "	+	4.0
	" "	V	1 36	AB = 1.2 "	+	2.5
	1909					
13	May 14	D	4 55.5	AB = 12′.6	+	5.5
	" "	H	4 55	AB = 13.0 mm.	+	6.0
	" "	V	4 48	AB = 0.8 "	+	6.0
14	Sept. 25	D	8 38	AB = 4′.4	W	2.5
	" "	H	8 36	AB = 3.8 mm.	+	5.0
	" "	V	8 34.5	AB = 0.4 "	+	10.0
15	Sept. 25	D	11 32[a]	AB = 2′.1	W	2.0
	" "	H	11 31	AB = 3.3 mm.	+	1.5
				BC = 5.5 "	—	4.5
				CD = 2.8 "	+	2.0
			11 39[b]	DE = 65.0 "	—	8.0
	" "	V	11 42	AB = 0.3 "	+	8.0
			11 50	BC = 10.1 "	—	7.0

(a) Later movements too faint for measurement.
(b) Movement goes beyond the sheet: 65 mms = amount actually registered.

Notes for Falmouth Data.

Year	Month	Element	Scale Values
1906	Throughout	D	1 centimetre = 11′.7 in arc.
"	"	H	1 millimetre = 5γ (1 cm = 0.0005 C. G. S.)
"	July and August	V	1 " = 5γ (1 cm = .0005 ")
"	December	"	1 " = 5.4γ (1 cm = .00054 ")
1907	Throughout	D	1 cm. = 11′.7 in arc.
"	"	H	1 mm. = 5γ (1cm = 0.0005 C. G. S.)
"	February	V	1 mm. = 5.1γ (1 cm = .00051 ")
"	July and October	"	1 mm. = 4.8γ (1 cm = .00048 ")
1908	Throughout	D	1 cm. = 11′.7 in arc.
"	"	H	1 mm. = 5γ (1 cm = 0.0005 C. G. S.)
"	March	V	1 mm. = 5γ (1 cm = .0005 ")
	August	"	1 mm. = 5.2γ (1 cm = .00052 ")
	September	"	1 mm. = 5.4γ (1 cm = .00054 ")
1909	Throughout	D	1 cm. = 11′.7 in arc.
"	May & September	H	1 mm. = 5.3γ (1 cm = 0.00053 C. G. S.)
"	" "	V	1 mm. = 5γ (1 cm = .0005 "

In all cases AB, BC, etc., represent successive movements.

THE ROYAL DUTCH METEOROLOGICAL INSTITUTE, DE BILT, MARCH 14, 1911

In reply to your letter I beg to send you herewith a list of the beginnings of the magnetic disturbances tabulated by Mr. R. L. FARIS, in *Terrestrial Magnetism*, v. XV, p. 101. The values are taken from the registration of the Adie-magnetograph with intermittent light; in determining the times we have also used the registration with permanent light of the Toepfer diagrams (cf. *Terrestrial Magnetism* v. XV, p. 31). The needles of the Adie-magnetograph have the dimensions 14 x 2 x 0.3cm. and an attached mirror; those of the Toepfer registration are smaller, diamond form, diagonal 5 and 2.5 cm., thickness 0.1 cm., with mirror ground on the needles. With regard to the difference in the times of beginning, indicated sometimes by the *Z* instruments, this communication may be of interest.

The times are given in $0^m.1$; as time of beginning is taken ½ minute after the last minute mark, belonging to the undisturbed or less disturbed part of the curve; in a few cases when minute mark at the beginning of a disturbance appeared to be lengthened, this time was taken as the beginning. The uncertainty of ½ minute resulting from giving the marks only every minute, is denoted in the last column by $\pm 0^m.5$. In the last column but one are given the uncertainties in the times, at which the minute contacts occured; because the contact work failed now and then this uncertainty is not always smaller than $0^m.1$.

In Table II are given the readings from minute to minute of *D*, *H*, and *Z* some minutes before and after the beginning of the disturbances. On reconstructing the curve by means of these figures you may get a correct view of the course of the disturbances at De Bilt, and at the same time you will be able to conclude, in case of doubt, what, in your opinion ought to be considered as the beginning of the disturbance.

The value of 1 mm. is:

D, 1906–1909, 1′.1.
H, 1906–1908, 3.7 γ; 1909, 3.4 γ.
Z, 1906–July, 4.2 γ; Aug. 4.3 γ; Dec. 4.7 γ;
1907–Febr. 4.9 γ; July 5.7 γ; Oct. 6.4 γ;
1908–7.2 γ; 1909—5.7 γ.

G. VAN DIJK,
Adj. Director of the Vth Section.

TABLE I. *Sudden Beginnings of Magnetic Storms at De Bilt (Adie Magnetograph).*

Date	D	H	Z	Uncertainty: Contacts	Uncertainty: Times	Remarks
1906	h m	m	m	m	m	
July 29	19	56.4	57.4	<0.1	±0.5	D, no distinct abrupt beginning.
Aug. 7	13 38.6	37.6	....	<0.1	±0.5	Z, no distinct abrupt beginning.
Dec. 21	.. ....	....	....	.....	.....	Needles continually in oscillation by strong decrease of temperature.
1907						
Feb. 9	.. ....	....	....	.....	.....	Times not exactly known, because of failing of 10 minute contacts.
July 10	.. ....	....	....	.....	.....	Times not exactly known, because of failing of 10 minute contacts.
Oct. 13	7 43.5	42.5	....	±0.3	±0.5	Z, no distinct abrupt beginning.
1908						
Mch. 26	17	41.0	....	±0.5	±0.5	D, times not exactly known. Z, smooth curve.
Aug. 19	0 14.0	14.0	....	±0.5	±0.5	Z, no abrupt change.
Sept. 11	7 21.2	21.2	....	<0.1	±0.5	Z, no abrupt change.
Sept. 11	21 48.1	46.1	48.1	<0.1	±0.5	H, $21^h48.^m1$ beginning of greater changes.
Sept. 28	8 41.0	41.0	42.0	±0.3	±0.5	According to Toepfer diagrams beginning of Z 1 to $1\frac{1}{2}^m$ after D and H.
Sept. 29	1 31.5	31.5	34.0	±0.3	.....	According to Toepfer diagrams beginnings of Z, D, and H are simultaneous. D and H points of $1^h 31.^m5$ somewhat lengthened.
1909						
May 14	4 55.3	55.3	55.3	±0.8	±0.5	Z, $5^h01.^m3$ beginning of greater changes.
Sept. 25	8 38.0	38.0	....	<0.1	±0.5	Z, beginning uncertain because of electric car disturbances.
Sept. 25	11 41.5	41.0	....	<0.1	H±0.5	D, point of $11^h41.^m5$ lengthened to a line of 8mm.; H, last minute mark $11^h 40.^m5$; Z, no distinct beginning because of electric car disturbances.

TABLE II. *Minute Scalings of Magnetograms at De Bilt.*

Gr. M. T.	D	H	Z
July 29, 1906			
h m	mm	mm	mm
19 50.4	32.3	30.3	24.1
50.9	32.1	30.4	24.1
51.9	32.0	30.5	24.2
52.9	32.0	30.5	24.1
53.9	32.2	30.5	24.2
54.9	32.2	30.6	24.2
55.9	32.3	30.5	24.2
56.9	32.4	28.3	24.1
57.9	32.2	37.9	24.3
58.9	32.4	46.5	24.0
59.9	32.3	47.7	23.7
20 00.4	32.8	46.9	23.5
0.9	32.9	46.4	23.5
1.9	33.2	46.0	23.0
2.9	33.4	45.3	22.9
3.9	33.6	44.0	22.7
4.9	33.7	44.5	22.6
5.9	33.8	44.0	22.8
August 7, 1906			
13 30.6	41.1	24.6	....
31.1	41.3	24.7	....
32.1	41.3	25.0	....
33.1	41.2	25.0	....
34.1	41.2	24.9	....
35.1	41.0	25.0	....
36.1	40.9	25.3	....
37.1	40.8	25.4	....
38.1	40.7	26.1	....
39.1	40.9	26.3	....
40.1	40.5	26.7	....
40.6	41.5	27.7	....
41.1	41.3	28.2	....
42.1	42.0	29.0	....
43.1	42.7	29.4	....
44.1	43.2	30.6	....
45.1	43.5	31.3	....
46.1	43.8	31.0	....

Gr. M. T.	D	H	Z
February 9, 1907			
h m m	mm	mm	mm
±14 7½	....	43.0	....
8½	....	43.4	....
9½	....	43.7	....
10½	....	43.7	....
11½	....	43.3	....
12½	....	44.0	....
13½	....	41.6	....
14½	....	56.8	....
15½	....	54.2	....
16½	....	53.2	....
17½	....	52.2	....
18½	....	50.0	....
19½	....	49.7	....
20½	....	50.0	....
21½	....	50.1	....
July 10, 1907			
±14 14½	....	23.9	....
15½	....	24.0	....
16½	....	24.0	....
17½	....	24.3	....
18½	....	24.9	....
19½	....	24.5	....
20½	....	24.3	....
21½	....	31.4	....
22½	....	33.0	....
23½	....	35.8	....
24½	....	35.8	....
25½	....	36.5	....
26½	....	35.9	....
27½	....	35.7	....
28½	....	34.6	....
October 13, 1907			
7 40.0±0.3	25.0	28.8	61.2
41.0	25.0	28.7	61.2
42.0	25.1	28.8	61.1
43.0	24.9	30.2	61.2
44.0	26.9	28.2	61.2
45.0	23.9	29.7	61.2
46.0	22.0	29.9	61.2
47.0	22.5	30.3	61.1
48.0	21.9	31.0	61.1
49.0	22.7	31.6	61.1
50.0±0.3	23.7	32.3	61.0

Gr. M. T.	D	H	Z
March 26, 1908			
h m m	mm	mm	mm
17 35.5±0.5	.....	42.6	....
36.5	.....	42.0	....
37.5	.....	42.0	....
38.5	.....	41.7	....
39.5	.....	41.6	....
40.5	.....	42.0	....
41.5	.....	44.8	....
42.5	.....	47.3	....
43.5	.....	50.9	....
44.5	.....	54.5	....
45.5	.....	54.4	....
46.5	.....	55.3	....
47.5	.....	57.0	....
48.5	.....	58.6	....
49.5	.....	59.7	....
50.5±0.5	.....	59.0	....
August 19, 1908			
0 10.5±0.5	30.2	32.2	65.0
11.5	30.3	32.3	65.0
12.5	30.5	32.4	65.0
13.5	30.8	32.8	65.0
14.5	30.2	33.6	65.0
15.5	32.1	38.3	65.0
16.5	34.2	41.7	64.9
17.5	36.3	43.9	64.8
18.5	38.0	44.5	64.7
19.5	38.5	43.4	64.5
20.0	38.3	43.0	64.4
20.5	38.4	42.7	64.3
21.5	38.7	42.7	64.2
22.5	39.1	42.6	64.2
23.5	38.9	42.5	64.2
24.5±0.5	38.6	42.4	64.2
September 11, 1908			
7 15.7	25.3	32.4	81.4
16.7	25.2	32.1	81.4
17.7	25.3	32.2	81.3
18.7	25.1	32.2	81.3
19.7	25.1	32.2	81.3
20.2	25.0	32.2	81.3
20.7	25.1	32.0	81.3
21.7	25.5	32.3	81.3
22.7	24.0	30.6	81.3
23.7	22.5	29.8	81.3
24.7	21.6	30.0	81.3
25.7	22.0	31.7	81.3
26.7	23.4	33.5	81.2
27.7	23.8	33.6	81.1
28.7	24.1	33.1	81.1
29.7	24.0	33.0	81.1
30.7	23.9	33.0	81.0

TABLE II. *Minute Scalings of Magnetograms at De Bilt.—Continued.*

Gr. M. T.	D	H	Z	Gr. M. T.	D	H	Z	Gr. M. T.	D	H	Z
September 11, 1908				September 29, 1908				September 25, 1909			
h m m	mm	mm	mm	h m m	mm	mm	mm	h m	mm	mm	mm
21 40.1	28.7	39.2	81.9	1 25.5±0.3	30.3	40.0	96.3	8 35.5	24.7	27.4	....
40.6	28.9	39.6	81.9	26.5	30.4	40.2	96.3	36.5	24.9	27.7	....
41.6	29.2	40.0	81.9	27.5	30.8	40.3	96.3	37.5	25.1	27.7	....
42.6	29.5	40.9	81.9	28.5	31.1	40.2	96.2	38.5	24.8	28.8	....
43.6	29.9	40.4	81.9	29.5	30.8	39.9	96.2	39.5	26.1	31.2	....
44.6	30.0	39.8	81.9	30.5	30.7	39.5	96.2	40.0	27.1	30.8	....
45.6	30.0	40.1	81.9	31.5	30.1	38.8	96.2	40.5	28.5	31.9	....
46.6	30.2	41.6	81.9	32.5	27.6	43.6	96.3	41.5	30.2	32.5	....
47.6	30.0	46.5	81.8	33.5	34.2	56.1	96.3	42.5	28.8	31.0	....
48.6	32.4	72.0	81.7	34.5	40.5	57.6	96.0	43.5	27.3	29.2	....
49.6	32.9	81.9	81.0	35.5	40.2	55.5	95.6	44.5	25.9	28.2	....
50.6	31.7	79.6	80.1	36.5	39.1	52.0	95.3	45.5	25.1	27.3	....
51.6	31.1	75.8	79.4	37.5	39.0	49.2	95.2	46.5	24.3	27.2	....
52.6	28.4	72.5	79.0	38.5	38.2	48.1	95.3	47.5	24.1	27.9	....
53.6	26.8	69.9	78.5	39.5	36.3	48.6	95.4	48.5	24.0	27.6	....
54.6	25.5	69.1	78.3	40.0	35.9	49.4	95.5	49.5	24.1	26.5	....
55.6	24.3	71.0	78.1	40.5	36.1	50.3	95.5	50.5	23.5	28.5	....
				41.5	37.2	51.6	95.5				
September 28, 1908				42.5	37.6	49.7	95.4	September 25, 1909			
				43.5	37.2	46.2	95.4				
8 35.5±0.3	27.2	33.8	95.5	44.5	36.2	42.6	95.6	11 30.5	26.3	22.6	40.0
36.5	27.0	33.8	95.5	45.5±0.3	34.5	41.0	95.8	31.5	26.2	22.7	40.0
37.5	26.9	33.8	95.5					32.5	26.8	30.1	40.3
38.5	26.8	33.7	95.5	May 14, 1909				33.5	27.7	23.4	40.4
39.5	26.8	33.8	95.5					34.5	28.2	21.7	39.8
40.0	26.8	33.8	95.5	4 49.8±0.8	31.9	49.4	39.6	35.5	26.6	20.7	39.6
40.5	26.8	33.8	95.5	50.8	32.4	49.9	39.6	36.5	25.2	21.2	40.0
41.5	27.8	34.8	95.5	51.8	32.8	50.1	39.6	37.5	24.7	17.8	39.9
42.5	24.7	31.7	95.3	52.8	33.3	49.6	39.6	38.5	25.6	19.9	40.3
43.5	26.2	30.1	95.4	53.8	33.4	50.1	39.6	39.5	26.9	22.0	40.2
44.5	24.7	29.9	95.4	54.8	33.3	50.1	39.6	40.0	26.9	17.5	40.2
45.5	23.8	29.8	95.4	55.8	32.7	51.1	39.7	40.5	26.2	22.5	40.2
46.5	23.0	32.1	95.4	56.8	32.7	51.9	39.6	41.5	17.0—25.0	....	40.3
47.5	22.7	33.4	95.3	57.8	34.6	54.3	39.6	42.5	24.0—25.4	....	40.2
48.5	23.8	35.5	95.2	58.8	35.4	58.0	39.5	43.5	20.8	....	40.9
49.5	24.2	36.6	95.1	59.3	37.2	59.5	39.5	44.5	14.4	....	41.1
50.5	24.1	36.9	94.8	59.8	39.7	62.5	39.5	45.5	10.9	....	42.6
51.5	24.5	38.4	94.5	5 0.8	43.8	68.0	39.4				
52.5	25.4	40.2	94.5	1.8	49.2	71.6	39.2				
53.5	26.2	40.9	94.2	2.8	53.0	69.5	39.0				
54.5	26.9	41.1	93.9	3.8	53.2	67.8	38.8				
55.5±0.3	28.2	40.8	93.7	4.8	53.9	67.5	38.8				
				5.8	57.2	66.5	38.8				
				6.8	57.3	64.8	38.8				
				7.8±0.8	57.6	64.1	38.9				

DET DANSKE METEOROLOGISKE INSTITUT, KJOBENHAVN, DEN 25 MARCH, 1911.

According to your wish in letter of 15th February, I have the pleasure to send you the enclosed list of magnetic data for the disturbances, as far as we are able to give them.

For the disturbances No. 1–4, we can not give any data, because our new magnetic observatory was not established at that time, and the old one was of no use on account of the electric tramways.

The time is given directly from the astronomical observatory in Copenhagen to the magnetic observatory in Rude Skov and as the clock, which is driving the drums, is going excellent and as the time-breaks arrive with a precision of ½ second the errors in time can be disregarded as far as concerns the breaks.

The errors in time for the sudden beginnings are then limited to the errors that arise from the photographic paper and the measurement of this. The mean error can be estimated to 1^m.

A specimen calculation is the following:

1909. Septbr. 25. Declination:

Difference between beginning of perturbation and nearest break —9.1 mm. As 120m is like 29.8 mm, 9.1 mm will give	—36m.6
Corrected local time for break	10h 04 .0
Correction for long. to Grw.	—49 .8
Grw. mean time for beginning of perturbation...	8h 37m.6

In some instances (especially in *Z*) the sudden beginnings were not sharp enough to be measured with sufficient accuracy. The time interval between the two co-ordinates could only be determined in a few cases.

Where the amount of the disturbance is not measured, it is because the result was dubious.

C. RYDER,
Director.

Greenwich Mean Times of Sudden Beginnings of Magnetic Storms at Rude Skov Observatory (Copenhagen).

Date	ΔD	D	ΔH	H	Time interval	ΔZ	Z
	′	h m	γ	h m	m	γ	h m
1907 July 10	−0.9	14 22.5	+ 45	14 23 5	....	+10	14 24.2
Oct. 13	+2.2	7 41.5	.....	.. ....	....	....	.. ....
1908 Mch 26	.....	17 42.8	.....	17 41.9	....	....	.. ....
Aug. 19	.....	.. ....	.....	0 13.3	....	....	.. ....
Sep. 11	+1.5	7 20.1?	+ 6	7 20.6?	....	....	.. ....
" 11	−2.0	21 47.1	+136	21 47.5	1.8	+31	21 47.2
" 28	+0.9	8 40.5?	− 25	8 43.4?	1.2?	− 7	8 42.4?
" 29	−5.2	1 31.4?	+ 62	1 33.1	1.4	+14	1 32.4?
1909 May 14	−2.7	4 55.4	.....	.. ....	....	....	.. ....
Sep. 25	−1.1	8 37.6	+ 17	8 37.7	....	....	.. ....
" 25	The sud den begin		ning occ urred whil		e the drums	were r	emoved.

OFICINA METEOROLÓGICA ARGENTINA, BUENOS AIRES, MAY 8, 1911.

Enclosed please find the data requested by you in your esteemed favours of February 15th and 17th, in regard to the magnetic disturbances tabulated in volume 15 of *Terrestrial Magnetism*. I also enclose the letter of transmission of Mr. L. G. Schultz, who is in immediate charge of the Pilar Station.

W. G. Davis, *Director*.

Observatorio Magnético, Pilar, *May 5, 1911*.

I have the honor to forward herewith the magnetic disturbance data requested by the Carnegie Institution together with tracings from our magnetograms for all the disturbances indicated. It is thought that the tracings will answer much more satisfactorily all requisites for seeking out "disturbance effects" than would readings of ordinates made here, since in one case the disturbance evidently began many hours earlier at Pilar than at other stations and in other cases there are so many small variations in *H* and none at all in the other two elements that it would be a hopeless task to make a satisfactory selection of points on the curves.

The following factors enable one to calculate the disturbance effects from ordinates read off from the accompanying traces:

Declination:	1 millimeter = 1′
	Mean value for period 9°36′ East
Horizontal Intensity:	1 millimeter = 1.8 gamma
	Mean value for period 0.25740 C. G. S.
Vertical Intensity:	1 millimeter = 1.0 gamma

The time scalings were made by three persons, each one working independently of the other two: the shrinkage of the photographic sheets as well as the parallactic effect of the lenses were taken into account. The large probable error during the night-time hours of 1906-07 are due to the lack of eclipses: since 1908 eclipses have been regularly made every two hours during the 24.

L. G. SCHULTZ.

Pilar Mean Civil Times of Sudden Beginnings of Magnetic Storms, 1906–1909.

No.	Date	Element	Pilar mean time	Prob. error	No.	Date	Element	Pilar mean time	Prob. error
	1906		h m	m		1908		h m	m
		D	9 08.0	0.3			D	19 58.0	0.2
1	July 29	H	9 10.1	"	8	Aug. 18	H	19 57.5	"
		Z	9 07.3	"			Z	19 57.0	"
		D	9 22.5	0.3			D	3 05.1	0.9
2	Aug. 7	H*	.. ....	...	9	Sep. 11	H	3 01.6	"
		Z*	.. ....	...			Z	3 05.3	"
		D	17 14.3	0.3			D	17 29.7	0.3
3	Dec. 21	H	17 14.6	"	10	Sep. 11	H	17 28.9	"
		Z	17 14.7	"			Z	17 30.1	"
	1907								
		D	20 55.0	0.3					
4	Feb. 8	H	20 54.2	"			D	4 25.9	0.8
		Z	20 55.0	"	11	Sep. 28	H	4 23.5	"
		D	5 02.1	0.8			Z	4 23.5	"
4	Feb. 9	H	5 01.3	"			D	21 17.4	0.4
		Z	5 03.0	"	12	Sep. 28	H	21 13.2	"
		D	9 55.8	0.3			Z	21 15.1	"
4	Feb. 9	H	10 00.0	"		1909			
		Z	9 58.1	"			D	0 41.4	0.3
		D	10 00.0	0.3	13	May 14	H	0 36.9	"
5	Jul 10.	H	10 08.1	"			Z	0 36.9	"
		Z	10 05.7	"			D	4 22.9	0.4
		D	3 29.1	0.9	14	Sep. 25	H	4 22.9	"
6	Oct. 13	H	3 27.1	"			Z	4 23.2	"
		Z	3 30.1	"			D	7 25.8	0.5
	1908				15	Sep. 25	H	7 25.8	"
		D	13 26.4	0.5			Z	7 26.0	"
7	Mch. 26	H	13 27.0	"					
		Z	13 27.0	"					

**H* and *Z* too fogged to make out detail.

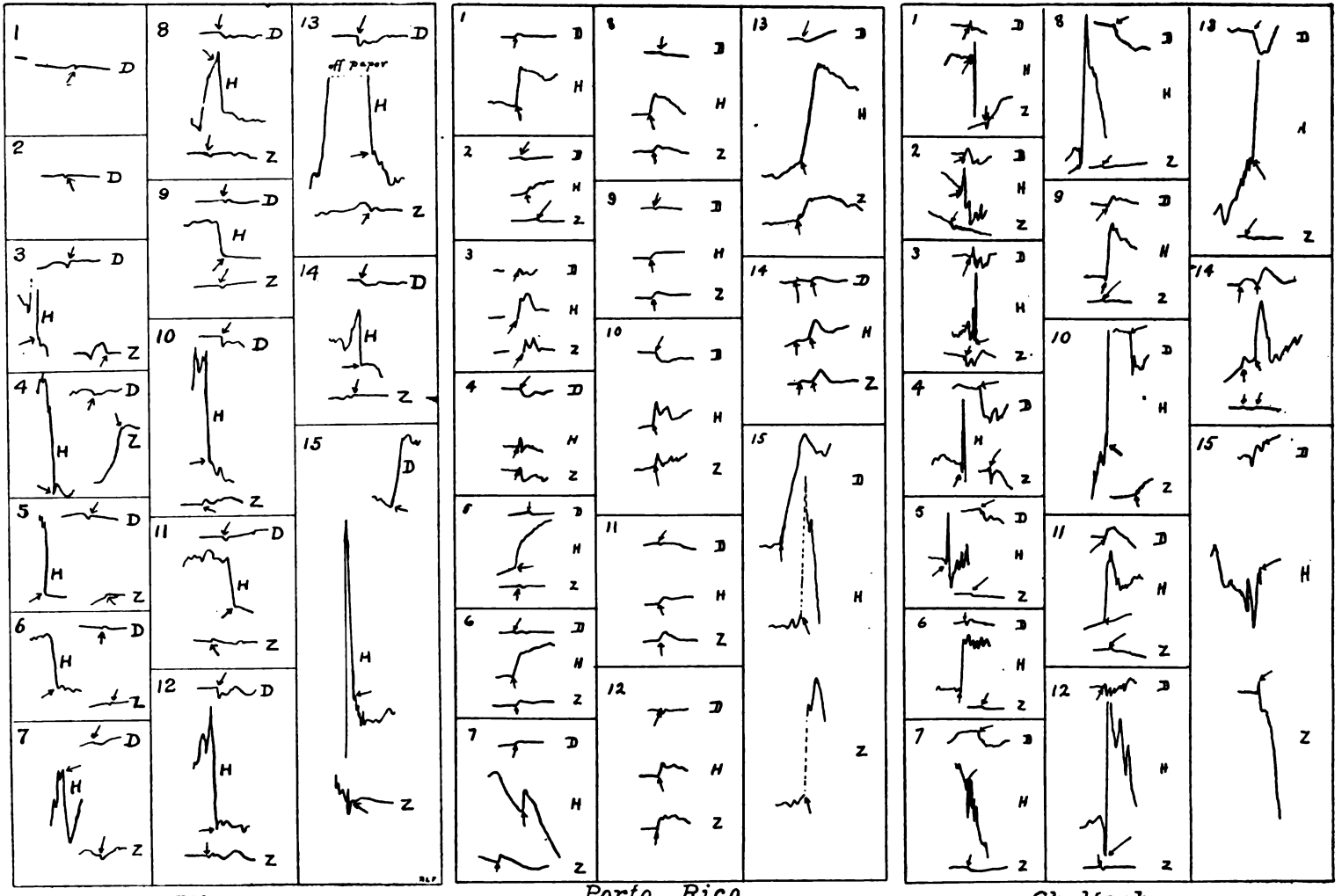
NOTE.—The figure showing the Pilar disturbances is reduced to about seven-tenths of the original size.

Duration and Magnitude of First Deflection in Magnetic Storms with Sudden Beginnings at the Pilar Observatory, 1906–09, Measured by R. L. Faris.

No.	Date	Component	First Deflection			△X	△Y	Remarks
			Duration	Magnitude				
				mm	*			
			m			γ	γ	G. M. T. h m
	1906	D	1.6	— 1.0	— 1.′0			19 58.3
1	July 29	H	...	.....	.....	....	.....	.. ....
		Z	...	.....	.....			.. ....
		D	2.4	— 1.0	— 1′.0			13 38.0
2	Aug. 7	H	...	.....	.....	....	.....	.. ....
		Z	...	.....	.....			.. ....
		D	4.0	+ 1.5	+ 1.′5			21 29.8
3	Dec. 21	H	1.6	+38.4	+69γ	+ 66	+ 23	30.1
		Z	4.0	— 2.8	— 3γ			30.2
	1907	D	3.0	— 1.0	—1′.0			14 11.3
4	Feb. 9	H	1.2	+20.7	+37γ	+38	— 2	15.5
		Z	8.0	— 9.7	—10γ			13.6
		D	1.0	+ 0.5	+ 0.′5			14 15.5
5	July 10	H	4.0	+14.5	+ 26γ	+25	+ 11	23.6
		Z	2.3	— 1.0	— 1γ			21.2
		D	4.0	— 1.0	— 1.′0			7 44.6
6	Oct. 13	H	6.0	+13.0	+ 23γ	+24	— 4	42.6
		Z	3.0	— 1.0	— 1γ			45.6
	1908	D	7.0	— 1.0	— 1.′0			17 41.9
7	March 26	H	4.8	—16.8	— 30γ	—28	— 12	42.5
		Z	4.0	+ 1.0	+ 1γ			42.5
		D	6.0	— 1.3	— 1.′3			0 13.5
8	Aug. 19	H	2.0	+ 3.6	+ 6γ	+ 8	— 9	13.0
		Z	1.0	+ 0.3	+ 0.′3γ			12.5
		D	1.2	— 1.0	— 1.′0			7 20.6
9	Sept. 11	H	6.5	+ 8.5	+ 15γ	+16	— 5	17.1
		Z	2.0	+ 0.8	+ 1γ			20.8
		D	3.0	— 2.3	— 2.′3			21 45.2
10	Sept. 11	H	2.0	+26.6	+48γ	+50	— 8	44.4
		Z	1.0	— 1.0	— 1γ			45.6
		D	2.7	— 0.6	— 0.′6			8 41.4
11	Sept. 28	H	5.2	+12.1	+22γ	+22	— 1	39.0
		Z	1.2	— 0.7	— 0.7γ			39.0
		D	2.0	— 2.6	— 2.′6			1 32.9
12	Sept. 29	H	2.0	+30.4	+55γ	+57	— 10	28.7
		Z	1.6	+ 0.8	+ 0.8γ			30.6
	1909	D	4.0	— 2.0	— 2.′0			4 56.9
13	May 14	H	6.0+	+18.3+	+33+γ	+35+	— 9+	52.4
		Z	3.0	+ 1.3	+ 1.3γ			52.4
		D	4.0	— 1.3	— 1.′3			8 38.4
14	Sept. 25	H	3.5	+13.3	+ 24γ	+25	— 6	38.4
		Z	2.4	+ 0.6	+ 0.6γ			38.7
		D	8.0	16.0	+16.′0			11 41.3
15	Sept. 25	H	4.0	42.3	+ 76γ	+54	+131	41.3
		Z	1.0	+ 4.0	+ 4γ			41.5

*Plus (+) sign means increasing easterly declination, increasing H and Z (in N. Mag. hemisphere).

$$\Delta X = 0.986\ \Delta H - 1.249\ \Delta D;\quad \Delta Y = 0.167\ \Delta H + 7.383\ \Delta D.$$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Pilar
Porto Rico
Magnetic Disturbances 1906 - 1909.
Cheltenham

METEOROLOGISCH MAGNETISCHES OBSERVATORIUM, POTSDAM, DEN 30. MAERZ, 1911.

Im Hinblick auf Ihren in Ihrem Schreiben vom 17. Februar ds. J. ausgesprochenen Wunsch, auch den Paragraph 2 Ihres Zirkulares vom 20. Dez. 1910 beantwortet zu sehen, beehre ich mich Ihnen folgendes mitzuteilen.

Sie wünschen den Störungseffekt kennen zu lernen, worunter Sie die Differenz zwischen dem ersten scharfen Umkehrpunkt und der Anfangsordinate verstehen. Bei dem Versuche, diese Differenz festzustellen, schien es aber zu unbestimmt, was im einzelnen Falle als erster scharfer Umkehrpunkt anzusehen sei. Es musste daher von einer numerischen Auswertung Abstand genommen werden.

Nun hätte es am nächsten gelegen, photographische Kopien der betreffenden Stellen der Kurven anzufertigen. Indessen fehlte hierzu die notwendige Zeit wegen anderer dringender Arbeiten. Es wurde daher zu dem Aushilfsmittel gegriffen, von den Störungsanfängen Pausen anzufertigen, die wir Ihnen anbei übersenden. Nach einer genauen Durchsicht weichen dieselben von den Originalen nirgends mehr als 0.2–0.3 mm ab. Die Punkte, auf welche sich die Zeitangaben in meinem Schreiben vom 21. Jan. beziehen, sind durch rote Striche bezeichnet. Um den Pausen absolute Werte zu entnehmen, sind folgende Umrechnungsfaktoren zu benutzen:

Es bedeutet 1 mm bei

		D	H	Z
1902	Mai	1′.00	3.14 γ	3.67 γ
1906	Juli	"	2.91	2.85
	August	"	"	"
	Dezember	"	"	3.10
1907	Februar	"	3.09	3.50
	Juli	"	"	3.60
	Oktober	0.522	"	3.40
1908	März	"	3.20	"
	August	"	"	3.50
	September	"	"	"
1909	Mai	"	3.35	4.00
	September	"	"	4.10

Steigende Ordination entsprechen wachsender westlicher Deklination, bezw. Horizontal- und Vertikal-Intensität. VENSKE.

ADDITIONAL INFORMATION FOR AGINCOURT OBSERVATORY (CANADA)

April 3, 1911.

Replying to your communication of the 17th ultimo, regarding the disturbance of September 25th, 1909, I would say that the earlier disturbance began at $8^h\,28^m\,37^s$, Greenwich Mean Civil Time. This movement whose beginning is well defined, is not the charac-

Duration and Magnitude of First Deflection in Magnetic Storms with Sudden Beginnings at Potsdam, 1906–09 (Venske), Measured by R. L. Faris.

No.	Date	Component	First Deflection			ΔX	ΔY
			Duration	Magnitude			
				mm	*		
			mm		′		
	1906	D	3.0	+ 1.6	+ 2	— 4	+10
1	July 29	H	0.8	— 2.0	— 6γ		
		Z	1.5	+ 0.6	+ 2γ		
		D	6.0	— 1.5	— 2′	+ 2	—11
2	Aug. 7	H	1.5	+ 1.5	+ 4γ		
		Z	3.0	— 0.4	— 1		
		D	3.6	+ 3.0	+ 3′	+ 63	+ 6
3	Dec. 21	H	4.5	+21.0	+61γ		
		Z	4.5	— 2.5	— 7		
	1907	D	3.0	— 4.6	— 5′	+ 45	—35
4	Feb. 9	H	3.0	+16.3	+ 50γ		
		Z	2.4	— 0.7	— 2		
		D	4.5	— 3.3	— 3′	+ 37	—23
5	July 10	H	1.2	+13.1	+ 40γ		
		Z	4.5	— 1.3	— 5		
		D	0.6	— 3.0	— 2′	+ 3	—12
6	Oct. 13	H	0.6	+ 1.7	+ 5γ		
		Z	5.4	— 1.5	— 5		
	1908	D	0.8	+ 4.9	+ 3′	+ 63	+ 6
7	Mch. 26	H	4.5	+19.0	+ 61γ		
		Z	3.6	— 1.5	— 5		
		D	0.8	+ 2.2	+ 1′	+ 31	0
8	Aug. 19	H	3.6	+10.0	+ 32γ		
		Z	5.1	— 1.4	— 5		
		D	0.8	— 1.8	— 1′	+ 6	+ 5
9	Sept. 11	H	0.8	+ 1.7	+ 5γ		
		Z	3.0	— 0.3	— 1		
		D	1.5	+ 1.4	+ 1′	+146	—18
10	Sept. 11	H	1.5	+46.0	+147γ		
		Z	3.0	— 7.7	— 27		
		D	1.5	+ 4.3	+ 2′	— 12	+14
11	Sept. 28	H	1.5	— 4.4	— 14γ		
		Z	1.5	— 0.6	— 2		
		D	1.2	+ 7.3	+ 4′	+ 67	+11
12	Sept. 29	H	1.5	+20.0	+ 64γ		
		Z	3.0	— 2.0	— 7		
	1909	D	0.8	+ 3.2	+ 2′	+ 56	+ 2
13	May 14	H	6.0	+16.3	+ 55γ		
		Z	4.8	— 1.7	— 7		
		D	2.4	— 8.1	— 4′	+ 8	—23
14	Sept. 25	H	1.2	+ 3.5	+ 12γ		
		Z	3.0	— 0.7	— 3		
		D	0.8	— 5.3	— 3′	+ 18	—20
15	Sept. 25	H	0.8	+ 6.3	+ 21γ		
		Z	0.8	— 6.6	— 27		

*Plus (+) sign means increasing easterly declination, increasing H, and Z.

$\Delta X = .987\Delta H + .884\Delta D$; $\Delta Y = -.161\Delta H + 5.42\Delta D$.

teristic one of a sharp movement to each side of the curve, but is an increase of west declination of 3'.8 in about $2^m\ 30^s$, whence there is a gradual decrease to the time at which the characteristic movement took place. R. F. STUPART.

ADDITIONAL DATA FOR THE OBSERVATORIES OF THE COAST AND GEODETIC SURVEY AT PORTO RICO, CHELTENHAM, BALDWIN, SITKA, AND HONOLULU

On March 16, 1911, the following self-explanatory request was made by the Director of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, to the Superintendent of the United States Coast and Geodetic Survey, as a result of the preliminary examination of the data that had at that time been received. The specimen curves referred to are reproduced in this and the preceding number of this JOURNAL.

"In addition to the data for the fifteen sudden disturbances between 1906 and 1909 already supplied, kindly furnish as soon as convenient time scalings of all the disturbances, separately for each element, taking into consideration the specimen curves from Potsdam and Kew, the tracings of which are enclosed herewith. Since the Kew curves are subject to a possible electric car disturbance, I would suggest that chief consideration be paid to the Potsdam curves, the precise point of scaling of which has been indicated by the observer (Dr. Venske). For Kew the time scalings have been supplied for each point as lettered, A, B, C, D, etc., no data being furnished for vertical intensity. You will also find enclosed the tracing of three specimen curves at Munich, which may be of further assistance to you.

"It appears that not all the fifteen cases at present under consideration present sufficiently sharp points at each observatory to admit of most accurate time scalings, and so it may be in your case; it will accordingly be desirable to furnish specimen curves for your own observatories showing the points considered in the scalings."

The additional data has been prepared by Mr. R. L. Faris, Inspector of Magnetic Work, and transmitted by Mr. O. H. Tittmann, Superintendent of the Survey.

NOTES ON THE TIME SCALINGS OF MAGNETIC DISTURBANCES 1906-09.

The appearance of the magnetograph record of a magnetic disturbance, and the form of the magnetic curves, as is well known, are not the same at different observatories, especially at places widely separated from each other, stations differing most in magnetic latitude apparently showing the greatest divergence in similarity of form of the magnetic curves during the prevalence of a magnetic storm. Consequently, in making comparisons of the

records of a magnetic storm at various places over the globe, it is often difficult to identify corresponding phases of the storm, even for those with so-called abrupt beginnings, inasmuch as at some of the stations the abrupt beginnings will be preceded by quite magnetically calm conditions, while at others disturbed conditions will immediately precede, and thus change the appearance and definition of the abrupt beginning of the storm. So that in making comparisons of the times of the abrupt beginning as shown on the records at various places it is necessary that these times correspond to the same phase of the disturbance.

In December, 1910, the Director of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington requested the directors of magnetic observatories throughout the world to furnish data from their observatories concerning the abrupt beginnings of the fifteen magnetic storms that had been discussed in the *Journal of Terrestrial Magnetism* for June, 1910.[1] It appeared from the notes and explanations accompanying the data received that in some cases the points selected for reading might not correspond to those that had been previously published in the paper above cited. In this view of the matter a re-reading of all of the fifteen disturbances has been made, having in consideration the points actually selected for reading by those at other observatories contributing data of these same disturbances, and accompanying which were diagrams on which the points which had been read, were indicated.

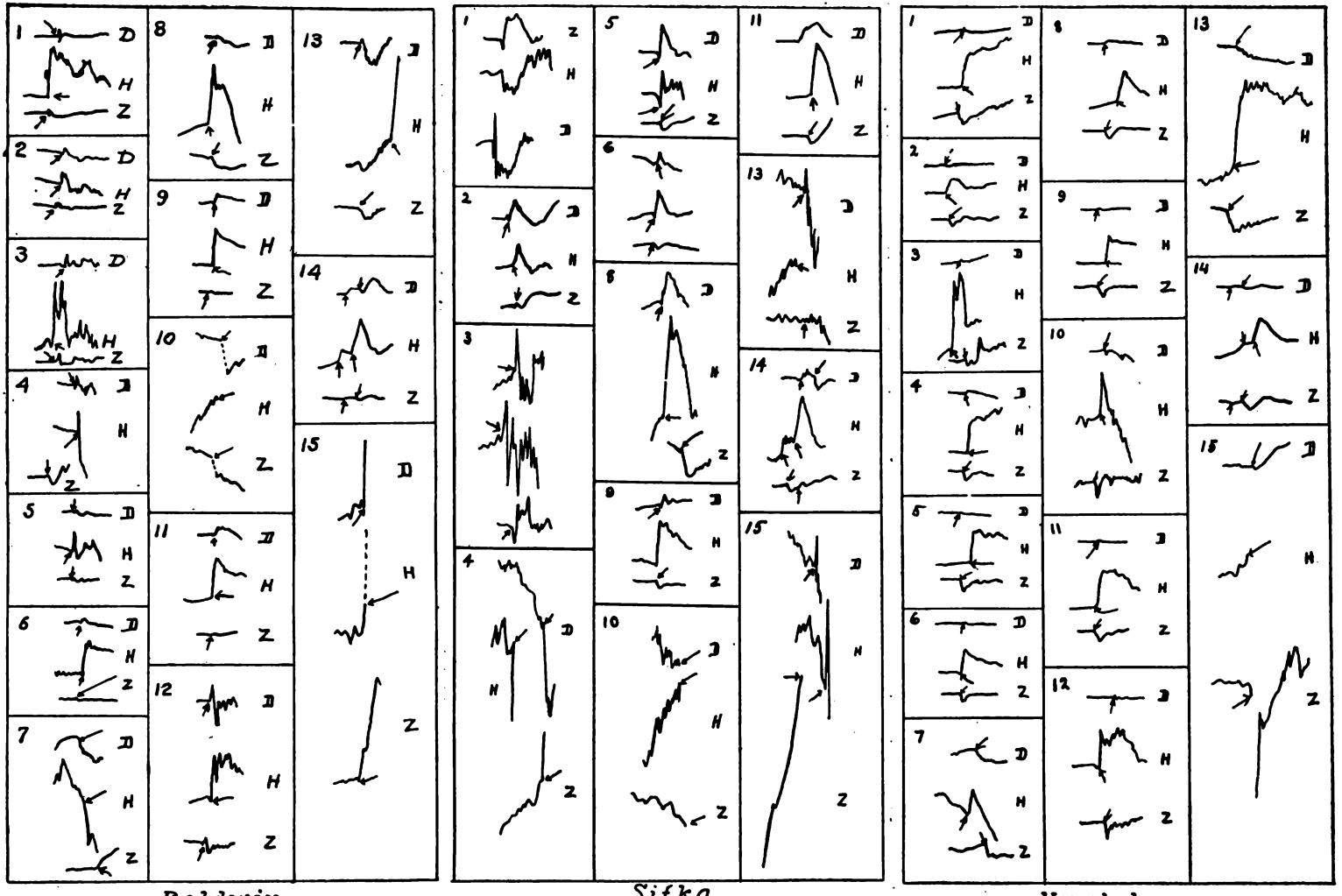
The values given in the tabulations are the mean of the two independent readings by two different persons, the points of the curves to be read being also independently selected by the two persons.

The method of reading the curves was to measure the distance from the beginning of the trace to the point to be read, then the distance on the base line from the beginning of the day's trace to the nearest hour break to the point to be read. The difference between the two readings was taken. Then the distance from the end of the day's trace to the point was measured, and also the distance from the end of the day's base line to the same hour break as in the first reading. The difference between the last two readings was then taken. This last difference should agree with the first difference above mentioned. The mean of these two differences, which is in millimeters, was then taken as the distance from the point to be read to the hour break. The mean difference was then converted into minutes of time and applied to the Greenwich mean time of the hour break. The accompanying table of "examples of time scalings of magnetic disturbances 1906-09" shows the method of the readings and the results of the two independent readings for the first four of the disturbances under con-

[1] FARIS, R. L.—Times of Abruptly Beginning Magnetic Disturbances, as Recorded at the Coast and Geodetic Survey Magnetic Observatories. *Terr. Mag.*, v. XV, pp. 93-105.

Greenwich Mean Times of Sudden Beginnings of Magnetic Storms, 1906–09, at the Magnetic Observatories of the United States Coast and Geodetic Survey.

No.	Date	Element	Observatory				
			Porto Rico	Cheltenham	Baldwin	Sitka	Honolulu
			h m	h m	h m	h m	h m
	1906	D	19 56.7	19 56.1	19 55.6	19 56.3	19 54.6
1	July 29	H	56.4	56.5	57.1	56.0	54.3
		Z	.. ....	55.8	55.8	57.2	54.7
		D	13 44.0?	13 38.8	13 39.2	13 40.7	13 37.6
2	Aug. 7	H	36.7	39.0	39.2	40.2	37.2
		Z	42.2?	42.0?	39.3	40.6	38.4
		D	21 33.9	21 31.6	21 31.4	21 30.2	21 30.6
3	Dec. 21	H	34.0	31.8	30.6	30.6	28.3
		Z	34.4	31.9	30.6	30.2	28.8
	1907	D	14 13.8	14 13.1	14 13.0	14 14.0	14 12.9
4	Feb. 9	H	13.1	13.2	13.0	13.5	12.0
		Z	13.3	12.4	13.4	13.5	12.4
		D	14 22.7	14 23.2	14 23.2	14 22.2	14 23.6
5	July 10	H	22.6	22.7	23.2	22.4	20.9
		Z	22.6	23.0	22.7	23.6	23.3
		D	7 42.6	7 42.0	7 42.8	7 43.2?	7 42.6
6	Oct. 13	H	43.4	43.0	43.3	44.0?	42.1
		Z	43.2	43.6	43.0	42.5?	42.4
	1908	D	17 41.7	17 43.8?	17 42.1?	.. ....	17 40.4
7	March 26	H	41.4	44.6?	42.2	.. ....	40.2
		Z	40.9	43.7?	42.3	.. ....	41.7
		D	0 14.9	0 14.8	0 14.4	0 15.2	0 15.1
8	Aug. 19	H	15.2	14.4	14.9	15.7	13.8
		Z	15.0	14.6? 16.9?	14.2	15.8	13.8
		D	7 20.6	7 20.0	7 21.0	7 21.0	7 21.8
9	Sept. 11	H	20.5	20.1	20.8	21.0	21.6
		Z	21.0	20.0	21.2	21.7	21.1
		D	21 47.6	21 47.2	21 46.0?	21 46.4	21 46.8
10	Sept. 11	H	47.2	46.7	49.1?	46.8	46.0
		Z	46.8	47.3	47.6?	47.0	45.8
		D	8 41.7	8 41.0	8 41.1	8 43.0	8 43.8
11	Sept. 28	H	40.8	41.3	41.6	42.9	43.1
		Z	42.4	42.6	42.6	42.6	43.4
		D	1 32.7	1 31.3	1 31.8	.. ....	1 31.8
12	Sept. 29	H	31.8	31.2	31.6	.. ....	32.0
		Z	33.8	31.9	31.8	.. ....	32.0
	1909	D	4 55.5	4 57.2	4 57.2	4 56.8	4 55.1
13	May 14	H	54.2	56.4	54.7	57.1	54.8
		Z	54.4	57.2	57.1	56.8	55.1
		D	8 30.0	8 28.5	8 29.0	8 31.1	8 29.2
14a	Sept. 25	H	29.6	29.4	28.8	30.5	30.7
		Z	29.3	29.1	28.8	31.0	30.7
		D	8 41.8	8 40.2	8 38.6	8 40.2	8 39.0
14	Sept. 25	H	38.6	39.0	37.7	39.8	37.9
		Z	39.2	37.8	38.4	40.0	38.6
		D	11 41.2	11 41.0	11 41.4	11 41.5	11 41.6
15	Sept. 25	H	40.8	41.2	40.5	41.0	40.6
		Z	40.8	41.7	42.2	45.2?	41.1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Baldwin

Sitka

Honolulu

Magnetic Disturbances 1906 - 1909.

sideration. In the fourth column of this tabulation B is the beginning of the day's trace, x the point, B in the 5th column is the beginning of the day's base line, and H is the hour break on the base line nearest to the point x. In the 7th column E is the end of the day's trace and E in the eighth column is the end of the day's base line. This method of reading is believed to yield all of the accuracy that can be obtained from time scalings on magnetograms with no more open time scale than 20 millimeters per hour. The differences shown in the two readings gives an idea of the accuracy attained in the determination of the time by the scalings. The differences shown are more largely due to the difference of opinion of the two persons in fixing upon the point to be read, than to errors of reading after the point has been decided upon.

The figures showing the disturbances at the Coast and Geodetic Survey Observatories are reduced to about seven-tenths of the originals.

Examples of Time Scalings of Magnetic Disturbances, 1906–09.

No.	Date	Mag. Element	B to x	B to H	Diff.	x to E	H to E	Diff.	Mean Diff.	G.M.T. of H.	G. M. T. of x	Mean Adopted
			mm	mm	mm	mm	mm	mm	mm	h m	h m	h m
		D	452.5	454.5	—2.0	27.7	25.8	—1.9	—5.8	20 02.0	19 56.2	
	1906	D	451.9	454.0	—2.1	27.7	25.8	—1.9	—6.0		56.0	19 56.1
	July	H	453.0	454.8	—1.8	28.0	26.2	—1.8	—5.4		56.6	
1	29	H	452.0	454.0	—2.0	27.5	25.8	—1.7	—5.6		56.4	56.5
		Z	453.0	455.0	—2.0	27.6	25.7	—1.9	—5.8		56.2	
		Z	452.0	454.5	—2.5	27.6	25.7	—1.9	—6.6		55.4	55.8
		D	321.9	309.3	12.6	156.4	168.6	12.2	37.2	13 02.1	13 39.3	
		D	321.2	309.0	12.2	156.4	168.4	12.0	36.3		38.4	13 38.8
	Aug.	H	321.5	309.3	12.2	156.5	168.8	12.3	36.8		38.9	
2	7	H	321.5	309.1	12.4	156.2	168.5	12.3	37.0		39.1	39.0
		Z	322.0	308.5	13.5	155.0	168.4	13.4	40.4	?)	42.5?	
		Z	321.6	308.5	13.1	155.0	168.1	13.1	39.3	?)	41.4?	42.0?
		D	5.2	15.2	—10.0	475.0	465.0	—10.0	—30.0	22 01.5	21 31.5	
		D	5.2	15.2	—10.0	474.7	464.8	— 9.9	—29.8		31.7	21 31.6
3	Dec.	H	5.4	15.3	— 9.9	475.5	465.5	—10.0	—29.8		31.7	
	21	H	5.4	15.3	— 9.9	474.7	464.9	— 9.8	—29.6		31.9	31.8
		Z	5.3	15.2	— 9.9	475.0	465.2	— 9.8	—29.6		31.9	
		Z	5.3	15.2	— 9.9	474.7	464.9	— 9.8	—29.6		31.9	31.9
		D	334.6	331.0	3.6	143.2	147.3	4.1	11.6	14 01.4	14 13.0	
	1907	D	334.8	330.8	4.0	143.2	147.1	3.9	11.8		13.2	14 13.1
4	Feb.	H	334.8	330.9	3.9	143.4	147.5	4.1	12.0		13.4	
	9	H	334.8	330.9	3.9	143.4	147.5	4.1	11.7		13.1	13.2
		Z	334.4	331.0	3.4	143.3	147.0	3.7	10.6		12.0	
		Z	334.6	330.9	3.7	143.1	147.0	3.9	11.4		12.8	12.4

PECULIAR MAGNETIC DISTURBANCES OF DECEMBER 28-31, 1908.

By R. L. Faris.

The following tabulation contains the data of the magnetic disturbances of December 28-31, 1908, as recorded by the Edelmann magnetographs at the Pilar magnetic observatory in Argentina.

Peculiar Magnetic Disturbances of Dec. 28–31, 1908, as Recorded at the Pilar Observatory, Argentina.

$\phi = 31°40'.4$ S. $\lambda = 63°51'.3$ W. of Gr. $= 4^h\ 15^m.5$ W. of Gr.	Mag. Element	Group I Dec. 29	Group III Dec. 30	Group B Dec. 30	Group C Dec. 30	Group D Dec. 30	Group IV Dec. 31
		h m	h m	h m	h m	h m	h m
Time of Beginning.....	D	17 32.0	10 34.7	(a)	17 48.3	18 57.3	(a)
	H	35.0	36.7	13 63.9	46.5	54.3	3 20.5
	Z	36.7	33.5	(a)	(a)	(a)	(a)
Time of Maximum.....	D	17 52.0	10 51.1	(a)	17 58.4	19 12.3	(a)
	H	54.0	49.9	14 14.7	54.7	05.9	3 30.6
	Z	52.1	49.5	(a)	(a)	(a)	(a)
Time of End..	D	18 06.2	11 11.5	(a)	18 17.5	19 36.7	(a)
	H	18 11.8	22.3	14 34.7	15.5	40.7	3 51.6
	Z	17 58.7	12.7	(a)	(a)	(a)	(a)
Duration of Deflection ..	D	34.2	36.8	....	29.2	39.4	....
	H	36.8	45.6	30.8	29.0	46.4	31.1
	Z	22.0	39.2	....	....	....	....
Maximum Deflection.....	D	+ 1'.2	+ 1'.7	.....	+ 1.'6	+ 1'.6	.....
	H	+23.4γ	+14.4γ	+ 9.5γ	+13.7γ	+ 9.7γ	+ 7.7γ
	Z	+ 1.0γ	+ 3.3γ	.....	.....	.....	.....
Character of Day.....	D	0	0	0	0	0	0
	H	1	0	0	0	0	0
	Z	0	0	0	0	0	0
	ΔD	+ 1'.2	+ 1'.7	.....	+ 1'.6	+ 1'.6	.....
	ΔH	+23.4γ	+14.4γ	+ 9.5γ	+13.7γ	+ 9.7γ	+ 7.7γ
	ΔZ	+ 1.0γ	+ 3.3γ	.....	.....	.....	.....
	ΔX	+22 γ	+12 γ	+ 9 γ	+12 γ	+ 8 γ	+ 7 γ
	ΔY	+13 γ	+16 γ	+ 2 γ	+14 γ	+13 γ	+ 1 γ
Appearance of Deflection ..	D	(C)	(B)	.....	(C) H	(B) Z	.....
	H	(B)	(B)	(B)	(B)	(B)	(B)
	Z	(B)	(C)	.....	.....	.....	.....

(a) Indefinite or not discernible.

This data was not available at the time of the publication[1] of the first collection of data of these peculiar disturbances, and hence

was not included in that collection. However, this data is of special interest and value, coming as it does, from one of the few magnetic observatories in south magnetic latitude.

The data is arranged in the same way as that heretofore published in the *Journal of Terrestrial Magnetism*.[1]

The magnetic character of the days were assigned by me, and are in accordance with the international scale (0, 1, and 2).

The ΔX and ΔY were computed from the ΔH and ΔD by the following relations:

$$\Delta X = 0.986\ \Delta H - 1.249\ \Delta D.$$
$$\Delta Y = 0.167\ \Delta H + 7.383\ \Delta D.$$

the mean value of D being taken as 9° 36′ East, and of H as 0.25740 C. G. S.

THE MAGNETIC CHARACTER OF THE YEAR 1910.

The annual review of the "Caractère magnétique de chaque jour," for 1910 has been drawn up in the same manner as the preceding years. Forty-three observatories contributed to the quarterly reviews; when the tables were prepared, thirty-four of them had sent complete data. One of the observatories communicated its method of classification; one adopted another method in the course of the year. Table II of the annual review, containing the mean character of each day and of each month, and the list of "calm days" is reprinted here.

G. VAN DIJK.

NOTES

12. The New Magnetic Observatory at Antipolo, Philippine Islands, is located 18.5 kilometers eastward of Manila at an altitude of about 215 meters above sea level. The approximate geographic co-ordinates are: latitude ,14°35.′8 north; longitude, 121°10′ east of Greenwich. The instruments were installed temporarily during May, 1910, but the Observatory was not completed and was not in regular operation until the beginning of the current year 1911. Acting Director M. Saderra Maçó gives the mean magnetic values deduced from absolute observations during July to December, 1910, as follows: declination, 0°39.′8 east; horizontal intensity, 0.38244 C. G. S.; dip, 16°17.′2 north.

[1] *Cf. Terr. Mag.*, v. 16, March, 1911, pp. 13-24.

TABLE SHOWING THE MAGNETIC CHARACTER OF THE YEAR 1910.

DATES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	MEAN
January	0.6	0.2	0.2	0.6	0.7	0.5	0.2	0.1	0.8	0.3	0.1	0.9	0.8	0.6	0.1	0.0	1.3	0.4	0.7	0.2	0.7	1.0	0.9	1.4	1.4	1.3	0.8	0.5	0.3	0.1	0.1	0.58
February	0.3	1.0	1.0	0.9	0.4	0.1	0.1	0.1	0.6	0.4	0.4	0.2	0.3	1.1	0.9	0.6	1.3	1.0	0.3	1.4	1.2	0.9	0.7	1.0	1.2	0.9	0.8	0.8				0.71
March	0.8	0.8	0.7	1.1	1.0	1.1	1.0	0.3	0.7	0.7	0.4	0.1	1.0	1.1	0.9	1.1	1.1	0.7	0.4	1.1	1.0	0.8	0.3	0.1	0.0	0.1	1.4	1.9	1.3	1.2	1.5	0.81
April	1.3	1.2	0.7	1.1	0.5	0.5	0.1	0.1	0.3	0.0	0.1	1.0	0.5	0.2	0.1	0.4	0.9	1.3	0.9	0.2	0.1	0.7	1.1	0.9	0.6	0.7	1.6	1.3	1.1	1.1		0.68
May	0.6	0.8	0.8	0.7	0.4	0.4	0.7	0.1	0.6	0.5	0.5	0.3	1.1	0.9	0.9	0.7	0.9	1.1	1.1	0.7	0.3	0.4	0.6	1.1	1.5	1.0	0.7	0.9	0.7	0.6	0.9	0.72
June	0.4	0.2	0.1	0.2	0.1	0.4	0.2	1.1	1.0	0.8	0.8	0.5	0.7	0.1	0.0	0.0	0.2	0.0	0.5	1.7	1.2	1.0	0.9	0.7	0.8	0.9	0.4	0.3	0.9	0.1		0.53
July	0.0	0.1	0.7	0.9	1.3	1.1	1.0	0.7	0.8	0.9	0.4	0.0	0.0	0.0	0.5	0.3	0.4	0.5	0.7	0.5	0.2	0.7	0.9	0.9	0.7	0.4	0.1	0.3	1.0	0.7	0.4	0.55
August	1.1	1.0	0.9	1.0	0.9	0.1	0.0	0.1	0.4	1.5	0.9	0.3	0.6	1.1	0.7	0.2	0.4	1.1	1.2	1.0	1.2	1.8	1.0	1.1	0.5	0.2	0.4	1.3	1.4	1.1	0.9	0.81
September	0.9	0.7	0.3	0.2	0.4	1.1	0.9	0.5	0.3	0.9	0.9	0.2	0.9	1.0	0.5	1.0	0.4	0.2	0.1	1.0	1.0	1.1	0.9	1.0	1.5	1.0	1.1	1.0	1.8	1.1		0.80
October	0.9	1.2	1.2	1.6	0.9	1.5	0.8	0.8	0.4	0.7	0.9	1.4	1.5	0.9	0.4	0.1	0.0	0.0	1.6	1.3	1.3	0.9	1.0	1.0	1.3	1.2	1.6	1.2	0.9	0.9	0.4	0.96
November	0.3	1.0	0.3	0.7	0.6	0.3	0.9	1.1	1.0	1.0	0.5	0.2	0.1	0.4	0.4	1.0	1.2	1.6	1.4	0.9	0.8	0.9	0.5	0.3	0.9	0.7	0.9	1.1	1.2	1.1		0.77
December	0.9	1.2	1.0	0.8	0.9	1.0	1.0	0.7	0.2	0.1	0.1	0.1	1.0	0.9	1.3	0.7	0.1	0.7	0.8	0.8	0.7	1.1	0.7	0.7	1.0	0.2	0.4	1.5	1.4	0.9	0.7	0.76

CALM DAYS

January	8,	11,	15,	16,	31.	February	6,	7,	8,	12,	19,	March	8,	12,	24,	25,	26.
April	7,	10,	11,	15,	21.	May	6,	8,	12,	21,	22.	June	2,	15,	16,	18,	30.
July	1,	12,	13,	14,	27.	August	6,	7,	8,	16,	26.	September	3,	4,	12,	18,	19.
October	9,	16,	17,	18,	31.	November	6,	12,	13,	14,	24.	December	10,	11,	12,	17,	26.

13. The Seismological Society of America has issued its first number (Vol. I, No. 1, March, 1911) of a journal to be published quarterly as the "Bulletin of the Seismological Society of America." This bulletin will be sent free to all members of the Society, the dues per year being $2, life membership $25. Inquiries concerning the Society or its publications and names proposed for membership should be sent to the Secretary, S. D. Townley, Stanford University, California.

14. Proposed Magnetic Observatories in Australasia. We note from *Nature* the following resolution passed at the January 9 to 14, 1911 meeting of the Australasian Association for the Advancement of Science at Sydney University:

"In view of the great scientific importance of continuous magnetic observations at selected stations, the council most strongly urges the establishment of magnetic observatories at Perth and Port Darwin, to supplement the long-continued and extremely valuable magnetic work of the Melbourne Observatory. The council learns with gratification that the reduction of the forty years' observations of the Melbourne Observatory is now completed, and would earnestly request that the Victorian Government authorize the printing of the results." The foregoing resolution to be brought to the notice of the Commonwealth, Victorian, and Western Australian Governments.

15. Personalia. Mr. T. F. Claxton, formerly of the Royal Alfred Observatory, Mauritius, has been appointed director of the British Colonial Observatory at Hongkong. *Dr. L. A. Bauer* met the magnetic survey yacht *Carnegie*, at Colombo, Ceylon, June 21, 1911, and accompanied her to Port Louis, Mauritius, and thence again to Colombo, where the party arrived September 10, 1911. *Magnetic Observer W. H. Sligh*, of the Carnegie Institution of Washington, has completed the magnetic survey overland through Asia Minor, in the Persian Gulf and the Red Sea, with intercomparison observations at the Magnetic Observatory at Helwan. He is now engaged in securing additional data in European Turkey and will then take up work in Tripoli, Tunis, Algiers, and Morocco, reoccupying at the same time a number of Moureaux's stations. *Magnetic Observer C. C. Stewart*, of the Carnegie Institution of Washington, has completed extensive magnetic work along the Amazon River and its tributaries in Brazil and Peru, and is now en route to Washington. *Magnetic Observer E. Kidson* took up during the early part of July, the magnetic survey of Australia as elsewhere related in this issue.

MEAN VALUES OF THE MAGNETIC ELEMENTS AT OBSERVATORIES[1]

COMPILED BY J. A. FLEMING.

Place	Latitude	Longitude	Year	Declination	Inclination	Intensity (C. G. S. units)	
						Hor'l	Vert'l
	° ′	° ′		° ′	° ′		
Pavlovsk..	59 41 N	30 29 E	1905	0 59.8 E	70 36.1 N	.16540	.46975
			1906	1 04.2 E	70 36.6 N	.16528	.46963
Sitka[2]....	57 03 N	135 20 W	1902	29 51.1 E	74 47.8 N	.15456	.56879
			1903	29 53.9 E	74 46.3 N	.15472	.56834
			1904	29 55.8 E	74 45.4 N	.15490	.56846
			1905	29 59.1 E	74 43.2 N	.15510	.56776
			1906	30 03.0 E	74 41.0 N	.15529	.56698
			1907	30 07.1 E	74 38.4 N	.15545	.56594
			1908	30 10.7 E	74 36.5 N	.15562	.56531
Katharinenburg..	57 03 N	60 38 E	1905	10 27.2 E	70 48.3 N	.17692	.50819
			1906	10 31.0 E	70 49.5 N	.17664	.50796
Rude Skov	55 51 N	12 27 E	1907	9 50.0 W	68 44.0 N	.17423	.44765
			1908	9 43.3 W	68 45 N	.17406	.44759
			1909	9 36.1 W	68 44 N	.17394	.44690
Eskdalemuir....	55 19 N	3 12 W	1908[3]	18 33.3 W	69 37.3 N	.16830	.45307
			1909	18 30.1 W	69 38.9 N	.16835	.45385
			1910	18 23.3 W	69 37.8 N	.16836	.45343
Stonyhurst...	53 51 N	2 28 W	1907	17 41.8 W	68 46.4 N	.17404	.44795
			1908	17 35.6 W	68 44.2 N	.17434	.44801
			1909	17 28.5 W	68 42.8 N	.17425	.44722
			1910	17 20.0 W	68 42.2 N	.17407	.44605
Wilhelmshaven ..	53 32 N	8 09 E	1907	11 59.4 W	.....	.18215	.....
			1908	11 54.1 W	67 31 N	.18171	.43905
			1909	11 46.8 W	67 30 N	.18129	.43767
			1910	11 37.0 W	67 30.5 N	.18124	.43773
Potsdam..	52 23 N	13 04 E	1906	9 29.6 W	66 18.4 N	.18879	.43022
			1907	9 24.0 W	66 19.0 N	.18866	.43010
			1908	9 18.0 W	66 19.5 N	.18853	.42989
			1909	9 10.6 W	66 20.0 N	.18834	.42971
			1910	9 02.9 W	66 19.6 N	.18828	.42945
Seddin....	52 17 N	13 01 E	1908	9 19.2 W	66 16.2 N	.18890	.42974
			1909	9 12.0 W	66 16.7 N	.18876	.42958
			1910	9 04.4 W	66 16.6 N	.18866	.42932

[1]From compilations by Dr. Charles Chree in "Report of the Observatory Department of the National Physical Laboratory for the years 1901, 1902, 1903, 1904, 1905, and 1906," and "Summaries of Results of Geophysical and Meteorological Observations in the year ended 31st December, 1910," at Kew, Falmouth, Valencia, and Eskdalemuir observatories; with additions by J. A. Fleming, Department Terrestrial Magnetism, Carnegie Institution of Washington. See tables for previous years in *Terr. Mag.*, v. IV, p. 135; v. V, p. 128; v. VIII, p. 7, and v. XII, p.175.

[2]Final yearly values.

[3]Absolute observations June and July.

Place	Latitude	Longitude	Year	Declination	Inclination	Intensity (C. G. S. units)	
						Hor'l	Vert'l
	° ′	° ′		° ′	° ′		
Irkutsk...	52 16 N	104 16 E	1905	1 58.1 E	70 25.0 N	.20011	.56250
De Bilt..	52 06 N	5 11 E	1906	13 24.2 W	66 53.3 N	.18569	.4351
			1907	13 19.0 W	66 49.9 N	.18559	.4337
			1908	13 12.8 W	66 47.2 N	.18551	.4326
			1909	13 06.5 W	66 47.8 N	.18544	.4326
Valencia..	51 56 N	10 15 W	1907	21 01.4 W	68 17.0 N	.17870	.44866
			1908	20 55.7 W	68 16.3 N	.17871	.44841
			1909	20 50.3 W	68 15.1 N	.17877	.44812
			1910	20 44.6 W	68 13.0 N	.17892	.44771
Clausthal.	51 48 N	10 20[4] E	1905	10 40.3 W	.....	.....	.....
Bochum ..	51 29 N	7 14 E	1907	12 17.4 W	.....	.....	.....
			1908	12 11.2 W	.....	.....	.....
Kew.....	51 28 N	0 19 W	1907	16 23.1 W	67 01.6 N	.18517	.43681
			1908	16 16.9 W	67 00.9 N	.18515	.43651
			1909	16 10.8 W	66 59.7 N	.18506	.43588
			1910	16 03.2 W	66 58.7 N	.18503	.43546
Greenwich	51 28 N	0 00	1906	16 03.6 W	66 55.3 N	.18524	.43474
			1907	15 59.8 W	66 56.1 N	.18533	.43522
			1908	15 53.5 W	66 56.3 N	.18528	.43518
			1909	15 47.6 W	66 54.0 N	.18526	.43432
Uccle.....	50 48 N	4 21 E	1905	13 53.7 W	66 03.8 N	.19069	.42956
			1906	13 49.0 W	66 02.9 N	.19080	.42949
			1907	13 42.9 W	66 02.3 N	.19048	.42859
			1908	13 36.7 W	66 01.6 N	.19061	.42867
			1909	13 29.7 W	66 00.9 N	.19030	.42772
Hermsdorf	50 46 N	16 14 E	1901	8 13.6 W	.....	.....	.....
			1902	8 08.9 W	.....	.....	.....
			1903	8 04.0 W	.....	.....	.....
			1904	7 59.3 W	.....	.....	.....
			1905	7 55.0 W	.....	.....	.....
			1906	7 49.8 W	.....	.....	.....
			1907	7 44.2 W	.....	.....	.....
			1908	7 39.0 W	.....	.....	.....
Beuthen..	50 21 N	18 55 E	1900	6 53.7 W	.....	.....	.....
			1901	6 49.1 W	.....	.....	.....
			1902	6 44.3 W	.....	.....	.....
			1903	6 39.0 W	.....	.....	.....
			1904	6 33.7 W	.....	.....	.....
			1905	6 27.9 W	.....	.....	.....
			1906	6 23.0 W	.....	.....	.....
			1907	6 17.9 W	.....	.....	.....
			1908	6 12.3 W	.....	.....	.....

[4]In the previous list (December, 1907) the longitude was given as 28°00′E, having been reckoned from the meridian of Ferro.

Place	Latitude	Longitude	Year	Declination	Inclination	Intensity (C. G. S. units)	
						Hor'l	Vert'l
	° ′	° ′		° ′	° ′		
Falmouth	50 09 N	5 05 W	1907	18 00.4 W	66 32.7 N	.18799	.43330
			1908	17 54.7 W	66 31.4 N	.18798	.43279
			1909	17 48.4 W	66 30.6 N	.18802	.43266
			1910	17 41.6 W	66 29.1 N	.18802	.43208
Prague	50 05 N	14 25 E	1907	8 31.4 W	.....	.....	.....
			1908	8 20.9 W	.....	.....	.....
			1909	8 15.1 W	.....	.....	.....
Cracow	50 04 N	19 58 E	1907	5 47.9 W	.....	.....	.....
			1908	5 44.6 W	.....	.....	.....
			1909	5 35.1 W	64 18 N	.....	.....
			1910	5 27.4 W	.....	.....	.....
St. Helier (Jersey)	49 12 N	2 05 W	1907	16 27.4 W	65 34.5 N	.....	.....
Val Joyeux	48 49 N	2 01 E	1907	14 45.9 W	64 46.5 N	.19740	.41900
			1908	14 39.6 W	64 44.6 N	.19735	.41831
			1909	14 32.9 W	64 43.9 N	.19727	.41792
Munich	48 09 N	11 37 E	1906	9 59.5 W	63 10.0 N	.20657	.40835
			1907	9 53.7 W	.....	.....	.....
			1908	9 47.3 W	.....	.....	.....
Kremsmünster[1]	48 03 N	14 08 E	1900	9 18.7 W	.....	.....	.....
			1901	9 16.8 W	.....	.....	.....
			1902	9 11.7 W	.....	.....	.....
			1903	9 06.7 W	.....	.....	.....
			1904	9 02.4 W	.....	.....	.....
O'Gyalla (Pesth)	47 53 N	18 12 E	1906	.....	.....	.....	.....
			1907	6 55.8 W	.....	.21142	.....
			1908	6 49.6 W	.....	.21127	.....
			1909	6 43.9 W	.....	.21094	.....
			1910	6 34.5 W	.....	.21076	.....
Odessa	46 26 N	30 46 E	1908	3 53.5 W	62 22.1 N	.21758	.41563
Pola	44 52 N	13 51 E	1907	8 49.3 W	60 07.0 N	.22214	.38656
			1908	8 43.2 W	60 06.8 N	.22208	.38640
			1909	8 36.2 W	60 06.1 N	.22194	.38599
Agincourt (Toronto)	43 47 N	79 16 W	1907	5 50.6 W	74 36.4 N	.16368	.59450
			1908	5 54.0 W	74 36.9 N	.16343	.59395
			1909	5 59.4 W	74 37.5 N	.16299	.59273
Perpignan	42 42 N	2 53 E	1907	13 04.4 W	.....	.....	.....
			1908	12 58.5 W	.....	.....	.....

[1]Three direct readings daily.

Place	Latitude	Longitude	Year	Declination	Inclination	Intensity (C. G. S. units)	
						Hor'l	Vert'l
	° ′	° ′		° ′	° ′		
Tiflis.....	41 43 N	44 48 E	1899	2 11.0 E	55 52.1 N	.25614	.37785
			1900	2 16.4 E	55 53.2 N	.25594	.37783
			1901	2 21.3 E	55 54.4 N	.25571	.37777
			1902	2 27.1 E	55 56.2 N	.25542	.37777
			1903	2 32.5 E	55 58.6 N	.25505	.37781
			1904	2 37.1 E	56 00.9 N	.25476	.37792
			1905	2 41.6 E	56 02.8 N	.25451	.37799
Capodimonte..	40 52 N	14 15 E	1905	8 45.3 W	56 15.0 N	.....	.....
			1906	8 40.3 W	56 13.5 N	.....	.....
			1907	.....	56 13.1 N	.....	.....
			1908	.....	56 13.0 N	.....	.....
			1909	.....	56 14.4 N	.....	.....
Ebro (Tortosa)...	40 49 N	0 31 E	1905	13 56.9 W	58 07.6 N	.23230	.37359
			1907	13 42.8 W	58 04.8 N	.23274	.37362
Coimbra..	40 12 N	8 25 W	1906	16 56.5 W	59 03.2 N	.22924	.38232
			1907	16 51.6 W	59 00.7 N	.22935	.38188
			1908	16 46.2 W	58 57.3 N	.22946	.38120
Mount Weather	39 04 N	77 53 W	1908	3 39.2 W[6]	.....	.....	.....
Baldwin[7]..	38 47 N	95 10 W	1901	8 21.9 E	68 34.5 N	.21953	.55944
			1902	8 23.0 E	68 37.6 N	.21948	.56081
			1903	8 24.8 E	68 40.0 N	.21915	.56113
			1904	8 26.3 E	68 40.6 N	.21878	.56048
			1905	8 27.6 E	68 43.0 N	.21843	.56070
			1906	8 29.7 E	68 44.2 N	.21810	.56048
			1907	8 31.4 E	68 46.2 N	.21764	.56024
			1908	8 33.0 E	68 47.8 N	.21714	.55972
			1909[8]	8 34.0 E	68 50.2 N	.21666	.55964
Cheltenham[9]...	38 44 N	76 50 W	1901[10]	5 05.0 W	70 21.5 N	.20215	.56643
			1902	5 06.8 W	70 21.9 N	.20198	.56612
			1903	5 10.0 W	70 22.7 N	.20158	.56543
			1904	5 13.3 W	70 24.0 N	.20121	.56507
			1905	5 17.8 W	70 25.4 N	.20084	.56474
			1906	5 21.5 W	70 26.9 N	.20044	.56438
			1907	5 26.0 W	70 29.0 N	.19992	.56402
			1908	5 31.1 W	70 30.5 N	.19942	.56344
Athens[11] ..	37 59 N	23 42 E	1904	5 20.2 W	52 09.1 N	.26275	.33691
			1905	5 18.2 W	52 09.5 N	.26140	.33598
			1906	5 10.4 W	52 11.9 N	.26099	.33604
			1907	4 59.8 W	52 07.3 N	.26016	.33477
			1908	4 53.0 W	52 11.7 N	.26197	.33613

[6]Dec. 1907 to June, 1908, trace readings.
[7]Final yearly values.
[8]January to October, 1909. Baldwin observatory succeeded by Tucson, Arizona, in October, 1909.
[9]Final yearly values.
[10]Six months, July to December.
[11]Electric car disturbances from 1904.

Place	Latitude	Longitude	Year	Declination	Inclination	Intensity (C. G. S. units)	
						Hor'l	Vert'l
	° ′	° ′		° ′	° ′		
San Fernando..	36 28 N	6 12 W	1906	15 36.5 W	54 52.6 N	.24796	.35251
			1907	15 31.8 W	54 52.8 N	.24809	.35273
			1908	15 25.6 W	54 48.4 N[12]	.24829	.35206
			1909	15 19.5 W	54 43.4 N[12]	.24849	.35126
Tokio....	35 41 N	139 45 E	1903	4 40.7 W	48 57.8 N	.29929	.34384
			1904	4 43.4 W	48 57.1 N	.29941	.34384
			1905	4 46.2 W	48 56.1 N	.29952	.34376
			1906	4 48.9 W	48 58.8 N	.29986	.34470
			1907	4 50.7 W	48 59.2 N	.29951	.34438
			1908	4 53.2 W	48 56.9 N	.29991	.34439
			1909	4 55.7 W	49 01.8 N	.30005	.34554
Zi-ka-wei .	31 12 N	121 26 E	1906	2 32.0 W	45 35.3 N	.33040	.33726
			1907	2 33.6 W	45 36.6 N	.33056	.33768
			1908[13]	2 35.4 W	45 35.4 N	.33078	.33766
Dehra Dun....	30 19 N	78 03 E	1906	2 39.2 E	43 29.8 N	.33365	.31625
			1907	2 38.2 E	43 36.1 N	.33324	.31735
			1908	2 36.7 E	43 42.2 N	.33293	.31819
Helwan...	29 52 N	31 20 E	1905	3 12.7 W	40 36.2 N	.30159	.25852
			1907[14]	3 01.1 W	40 39.3 N	.30028	.25787
			1908	2 55.7 W	40 39.4 N	.30033	.25793
			1909	2 49.2 W	40 40.4 N	.30031	.25804
			1910	2 41.5 W	40 40.5 N	.30029	.25806
Barrackpore....	22 46 N	88 22 E	1906	1 14.1 E	30 26.4 N	.37259	.21894
			1907	1 09.8 E	30 30.2 N	.37288	.21967
			1908	1 05.6 E	30 34.6 N	.37298	.22037
Hongkong	22 18 N	114 10 E	1906	0 07.0 E	31 05.8 N	.37037	.22339
			1907	0 05.9 E	31 03.0 N	.37009	.22281
			1908	0 03.8 E	31 02.4 N	.37056	.22301
			1909	0 02.2 E	31 00.5 N	.37091	.22293
Honolulu[15]...	21 19 N	158 04 W	1902	9 19.1 E	40 14.5 N	.29284	.24783
			1903	9 19.8 E	40 12.3 N	.29257	.24728
			1904	9 20.9 E	40 09.4 N	.29237	.24669
			1905	9 21.7 E	40 05.8 N	.29226	.24608
			1906	9 23.0 E	40 02.0 N	.29220	.24547
			1907	9 24.3 E	39 59.1 N	.29201	.24489
			1908	9 25.7 E	39 55.3 N	.29188	.24424
Toungoo..	18 56 N	96 27 E	1906	0 43.6 E	22 59.2 N	.38715	.16423
			1907	0 39.3 E	23 01.5 N	.38754	.16470
			1908	0 34.4 E	23 01.9 N	.38763	.16479

[12]Absolute observations only.

[13]January and February only. Succeeded by new observatory at Lu-kia-pang (Φ=31°20′N, λ=120°01′E) in March, 1908. The observatory at Zi-ka-wei had been in operation 31 years and was discontinued on account of electric car lines in Shanghai.

[14]Watson magnetograph, April through December.

[15]Final yearly values.

Place	Latitude	Longitude	Year	Declination	Inclination	Intensity (C. G. S. units) Hor'l	Vert'l
	° ′	° ′		° ′	° ′		
Alibág....	18 38 N	72 52 E	1907	1 03.8 E	23 15.5 N	.36862	.15843
			1908	1 02.2 E	23 21.8 N	.36857	.15922
			1909	1 00.3 E	23 28.4 N	.36845	.16008[16]
			1910	0 57.7 E	23 36.3 N	.36845	.16101[16]
Vieques[17] .	18 09 N	65 26 W	1903[18]	1 23.2 W	49 10.0 N	.29365	.33980
			1904	1 31.0 W	49 15.0 N	.29295	.33999
			1905	1 38.3 W	49 17.0 N	.29250	.33986
			1906	1 45.9 W	49 22.1 N	.29202	.34033
			1907	1 53.7 W	49 29.3 N	.29135	.34099
			1908	2 02.5 W	49 36.3 N	.29050	.34140
Antipolo..	14 36 N	121 10 E	1910[19]	0 39.8 E	16 17.2 N	.38244	.11174
Kodaikanal...	10 14 N	77 28 E	1906	0 36.3 W	3 21.1 N	.37425	.02192
			1907	0 40.7 W	3 27.4 N	.37431	.02260
			1908	0 45.4 W	3 33.2 N	.37434	.02324
Batavia-Buitenzorg[20]...	6 11 S	106 49 E	1905	0 55.0 E	30 39.7 S	.36690	.21752
			1906	0 54.1 E	30 48.5 S	.36708	.21889
			1907	0 52.2 E	30 55.2 S	.36710	.21988
St. Paul de Loanda.	8 48 S	13 13 E	1904[21]	16 45.5 W	35 07.0 S	.20242	.14235
			1905	16 35.4 W	35 12.0 S	.20182	.14237
			1906	16 30.0 W	35 15.9 S	.20196	.14281
			1907	16 25.9 W	35 22.0 S	.20205	.14341
			1908	16 20.4 W	35 21.7 S	.20181	.14322
			1909				
			1910	16 12.3 W	35 32.2 S	.20125	.14374
Samoa (Apia)..	13 48 S	171 46 W	1905	9 37.0 E	(29 11.6 S)	.35678	(.19935)
			1906	9 38.5 E	29 15.7 S	.35655	.19977
			1907	9 40.1 E	29 18.8 S	.35637	.20010
			1908	9 41.9 E	29 21.7 S	.35613	.20036
Tananarive....	18 55 S	47 32 E	1907	9 29.7 W	54 05.7 S	.25330	.34986
Mauritius.	20 06 S	57 33 E	1907	9 13.6 W	53 49.0 S	.23461	.32075
			1908	9 14.3 W	53 44.9 S	.23415	.31932
			1909	9 16.3 W	53 39.8 S	.23377	.31781
Rio de Janeiro...	22 55 S	43 11 W	1906	8 55.3 W	13 57.2 S	.24772	.06169
Santiago..	33 27 S	70 42 W	1905	14 27.0 E	30 25.0 S	.....	.....
			1906	14 18.7 E	30 11.8 S	.....	.....
			1907	14 08.7 E	29 55.3 S	.....	.....
			1908	14 05.4 E	29 55.3 S	.....	.....
			1909	13 57.9 E	29 57.2 S	.....	.....

[16]The values of I and Z for 1909 and 1910, as given in the table, are those determined with Kew type of dip circle. Determinations were also made with a Schulze earth inductor, as follows: 1909, I=23 30.′0N, Z=.16033; 1910, I=23 39.′6N, Z=.16143.

[17]Final yearly values.

[18]April to September. All values referred to the new absolute observatory built in 1907.

[19]Absolute observations, July to December; succeeding Manila observatory.

[20]Use is made of magnetograph records from Buitenzorg (Φ=6 35′S, λ=106 47′E), but the absolute values apply apparently to Batavia. Observatory at Batavia discontinued April 1, 1899, account of electric car disturbances.

[21]Means of monthly absolute observations (3 to 4 monthly).

LETTERS TO EDITOR

THE MAGNETIC SURVEY OF AUSTRALIA.

Australia is at present the largest land area in which so comparatively few magnetic observations have been made. With the exception of the portion of Victoria, of which a magnetic survey embracing about 235 points was carried out by the indefatigable Neumayer, between 1858 and 1864, the preliminary magnetic survey of Tasmania by McAulay and Hogg in 1901, and some isolated observations along the coasts, such magnetic results as exist in the interior are confined, well-nigh exclusively, to compass observations by surveyors.

If it be remembered that the total area involved is over three-fourths that of entire Europe, and is practically equal to that of the United States (exclusive of Alaska), it will readily be appreciated that there remains here an important field for magnetic exploration. And the importance does not arise merely from purely scientific considerations, but from practical ones as well—navigation, surveying, and exploration of the great interior reaches. The prevalence of local disturbances at some of the ports of call is well known, and mention should be made here of the remarkable local disturbances revealed at Port Walcott on the northwest coast, by the admirable work of H. M. S. *Penguin*, 1890-93.

I am happy to be able to report that a general magnetic survey of Australia, under the combined auspices of governmental organizations and of the Carnegie Institution of Washington, has now been set in progress. As the result of various conferences, the following will be the general lines on which the proposed work is to be conducted.

1. The Melbourne Observatory, under the direction of Mr. Barrachi, will be the principal base station of the Magnetic Survey; secondary base stations will be located near the capitals of the other states where magnetic observations at frequent intervals, and declination readings at certain agreed times, will be made by local officials. Sydney already has such a sub-base station in progress in connection with its Observatory.
2. The Carnegie Institution of Washington has assigned one of its experienced observers, Mr. Edward Kidson, M. A., a former assistant of Dr. Farr's, at Christchurch, but connected with the Department of Terrestrial Magnetism of the above Institution during the past four years, to take charge of its own magnetic work in Australia and outlying islands. Mr. Kidson has been instructed, furthermore, to keep in

touch with the existing organizations, governmental and otherwise, interested in the work, and to render every assistance possible in the training of others. Mr. Eric N. Webb, of Christchurch, has been assigned to assist Mr. Kidson until the former is ready to join the Mawson Antarctic Expedition.

3. The Institution, through its Department of Terrestrial Magnetism, lends as far as possible complete magnetic outfits to such organizations as are in a position effectually to co-operate and which, for one reason or another, can not immediately secure the requisite instruments.
4. The work of the Institution will be confined to obtaining, on the average, about one station to every ten thousand square miles, where the three magnetic elements (declination, dip, and intensity) will be determined, or, in other words, the average distance between stations will be about one hundred miles. Since the total area is nearly three million square miles, the General Survey will have about three hundred stations, and it is hoped that this number will certainly be completed by the end of 1913, when the Institution will attempt to construct its first general magnetic charts for the region 80° North to 60° South. It will, of course, not always be possible, primarily because of difficulty of access and of travel, to maintain the average distance of one hundred miles. About ten per cent of these stations will be selected with a special view of serving as "repeat" stations for determining the secular changes, as well as meeting the requirements of correlation or connecting stations for the work done by others.
5. All detailed work in which the distance between stations will be considerably less than one hundred miles will be left to the co-operating organizations and to local enterprise. [It is gratifying to state that considerable interest has already been evinced in the accomplishment of this detailed work. To mention but one instance: Upon my arrival at Perth, West Australia, I found that steps had already been taken by the Department of Lands and Surveys to secure a magnetic survey of West Australia.]

One of the first trips to be undertaken as soon as possible by the observer of the Carnegie Institution of Washington is a series of stations right through the central part of Australia, from Adelaide to Port Darwin; this will involve about eleven hundred miles' travel by camel. The Surveyor-General of South Australia, through his deputy, E. M. Smith, Esq., has promised his hearty co-operation.

While at Melbourne, a conference was held between the Committee in charge of the Scientific Work of the Mawson Antarctic Expedition and myself, and as the outlook is promising for the ac-

complishment of useful magnetic work in the Antarctic, between Cape Adare and Gaussberg (170° and 90° East longitude), it was agreed that the Department of Terrestrial Magnetism supply the necessary outfits for magnetic survey work, as well as to train an observer who, Mr. E. N. Webb, above mentioned, after he joins the Expedition, will have his services defrayed by the Expedition.

Yacht "Carnegie," L. A. BAUER.
Colombo, June 21, 1911,
Ceylon, India.

PRINCIPAL MAGNETIC STORMS RECORDED AT THE CHELTENHAM MAGNETIC OBSERVATORY.

JANUARY 1 TO JULY 2, 1911.

Latitude: 38 °44.'0 N; Longitude: 76 °50.'5 or 5h 07m.4 West of Greenwich.

GREENWICH MEAN TIME				RANGE		
Beginning		Ending		D (Declination)	H (Hor'l Int.)	Z (Vert'l Int)
Day	h m	Day	h	′	γ	γ
Jan. 2,	2 15	Jan. 4,	3	20.9	82	21
Jan. 8,	16 49	Jan. 11,	17	25.3	89	36
Jan. 23,	16 28	Jan. 29,	8	21.3	111	53
Jan. 30,	22 44	Feb. 3,	9	29.3	82	48
Feb. 4,	18 03	Feb. 8,	18	14.3	74	25
Feb. 12,	17 19	Feb. 15,	10	23.7	84	48
Feb. 17,	4 23	Feb. 19,	5	17.1	86	22
Feb. 20,	22 55	Feb. 24,	11	37.2	117	88
Feb. 25,	19 42	Mar. 1,	14	19.3	100	49
Mar. 4,	19 01	Mar. 6,	15	22.9	94	32
Mar. 20,	00 41	Mar. 22,	11	35.1	140	94
Mar. 22,	23 22	Mar. 24,	13	24.5	95	48
Mar. 25,	00 48	Mar. 28,	9	26.5	116	66
Mar. 28,	23 25	Mar. 29,	19	17.0	61	36
Apr. 8,	11 19	Apr. 11,	01	42.1	200	200
Apr. 15,	23 01	Apr. 17,	13	28.0	98	90
Apr. 18,	03 14	Apr. 20,	09	18.4	76	39
Apr. 20,	23 00	Apr. 23,	13	16.8	71	50
Apr. 30,	05 35	May 1,	01	17.8	74	62
May 6,	12 58	May 8,	09	25.6	103	88
May 14,	17 00	May 18,	13	28.7	171	120
May 30,	05 24	June 1,	21	20.1	68	48
June 3,	17 32	June 5,	15	22.7	78	70
June 9,	16 33	June 12,	9	27.4	139	82
June 12,	18 32	June 15,	5	14.2	77	39
June 30,	21 46	July 2,	15	23.8	123	44

O. H. TITTMANN, *Superintendent, Coast and Geodetic Survey.*

J. E. BURBANK, *Observer-in-Charge.*

DIRECTIONS FOR MAGNETIC MEASUREMENTS.[1]

Magneticians generally will welcome the appearance of this publication, both because of its excellent presentation of the essentials of field and office practice and because of its general suggestiveness. Its aim is "to present the subject matter in such form that an observer familiar with the use of instruments of precision but without experience in magnetic work may be able to make in satisfactory manner the various observations incident to the determination of the magnetic elements, without other assistance than that to be obtained from these Directions." Not only has the author effected this purpose but he has also covered the subject of magnetic computations as fully as that of observation, by concise derivation of the various formulae involved, the discussion of their use, and numerous tables particularly helpful to the practical computer. The manual presents in a very concise and finished form, the results of the experience of the United States Coast and Geodetic Survey since its magnetic work was placed on a systematic basis by C. A. Schott, and developed subsequently, in the separate Division of Terrestrial Magnetism of that Survey, under the direction of Dr. L. A. Bauer; the system of observation, and reduction of results, as well as the general directions to observers in the field as given, are essentially those developed by the latter on the foundation laid by Schott.

After a short introduction, giving a brief account of terrestrial magnetism, derivations of the various formulae necessary for the determination of the magnetic elements are given, together with a discussion of the various observation corrections necessary. The subject of the determination of the constants of a magnetometer is carefully detailed. The discussion of the Coast and Geodetic Survey methods as regards the troublesome question of distribution coefficients is of particular interest. The rather tedious observation and computation of these coefficients is simplified for the instruments designed by the Survey, by the adoption of a ratio of length of long magnet to length of short magnet such that the first coefficient, P, is practically zero, this ratio being, from the relation $P = 2l^2 - 3l_1^2$, where l and l_1 are the lengths of the long and short magnets respectively, 1.225. In practice it is found that under

[1] HAZARD, D. L.—Directions for magnetic measurements. United States Coast and Geodetic Survey. Government Printing Office. Washington. 1911.

these conditions the value of P as computed from deflections at two distances, neglecting subsequent coefficients, is between zero and —1. The value of the second coefficient, Q, may then be supplied from the formula and a revised value of P taken, but it is shown that all terms except that in P may in this type of instrument be omitted with an error within one part in 5000. If, in the course of the season's work a systematic difference is shown in the values of log H/m at the two distances, P may be readily corrected from the relation

$$\Delta P = \log_e 10 \frac{r_2^2 r_1^2}{r_2^2 - r_1^2} \left[\log\left(\frac{H}{m}\right)_2 - \log\left(\frac{H}{m}\right)_1\right]$$

These magnetometers are so arranged that there are only two deflection distances. It would seem, however, more satisfactory, especially where the survey is to cover very wide ranges in horizontal intensity, to provide additional deflection distances so that two pairs of deflection distances might be employed, in which case values for both P and Q might be obtained from the field observations without the use of the more cumbersome method of deflections at three distances. For example, where distances 30 and 40 cm. are used for comparatively low values of horizontal intensity, 27.5 and 35 cm. may be used for higher values of the horizontal intensity. The ratio of the horizontal intensity to the magnetic moment at 30 cm. when equated to the value at 40 cm. gives an equation of the form: $aP + bQ = K$; similarly a second equation can be formed for the observations at 27.5 and 35 cm. The computation of the coefficients by such a method is quickly made and obviates any uncertainties resulting from neglecting the coefficient Q.

In the chapter of general directions for the use of observers making land observations a large section is devoted to the details of the selection, description and marking of stations, and quite properly, for these parts of the observer's work are of very great importance and there is unfortunately a general tendency to give them only secondary attention. More time is often required to select and mark a station than to make the observations, but such time is well spent since observations made at an improper location are worse than useless and a station not well marked either by monument or by detailed description can not be safely used for secular variation determinations. Secular variation data from fixed observatories cover but a very small portion of the whole

land area to be surveyed and for the larger part secular variation data from field repeat stations must be relied upon. If all observers would select and mark or describe their stations with the care contemplated in these instructions much of the uncertainty in secular variation data now ascribed to instrumental or observational imperfection would doubtless be eliminated. Detailed specimens and instructions for the use of theodolite, magnetometer, compass declinometer, dip circle compass attachment, dip circle, and earth inductor for the determination of declination, dip, horizontal and total intensity, together with descriptions of the types of instruments used, follow. The adoption of fixed forms for each class of observation is without question of much importance in the very rapid prosecution both of the field and office work in the operations and publication of the Survey.

A chapter is devoted to directions for observations at sea. The development in the instrument shop of the Survey of the Lloyd-Creak dip circle so that total intensity work can be carried out throughout the world by the provision of two deflection distances is of particular interest. This is followed by a chapter of directions regarding the installation and operation of variation instruments as used at the magnetic observatories of the Survey. It is interesting to note here again the care with which all routine work has been systematized and reduced to a uniform basis by the use of forms.

There is appended to the manual a section giving such tables as are useful for magnetic computations, including, for example, tables of refraction and parallax, correction in latitude and azimuth for sun's semi-diameter, constants for reducing circum-meridian altitude observations, corrections to be applied to the time of one oscillation for torsion effect and chronometer rate, and tables of mean diurnal variation in the elements as obtained at the observatories of the Survey for two or more years preceding 1906.

This work is a very useful and valuable compilation and is put out in a form which adapts it peculiarly to the use of the man in the field as well as the computer. Its publication and distribution among magneticians not only provides a useful manual but will furnish the standard by which the comparative efficiency of the magnetic work of the Coast and Geodetic Survey may be measured. A comparison of the details of field work and office reduction as set forth in this manual with those of other organizations as they may appear from time to time will assist in giving proper weight to the results of various agencies engaged in gathering magnetic data and thus materially aid the completion of the project of the magnetic survey of the entire earth. H. W. Fisk.

Department Terrestrial Magnetism,
Carnegie Institution of Washington.

THE "CARNEGIE" AT PORT LOUIS, MAURITIUS, AUGUST, 1911.

Terrestrial Magnetism

and

Atmospheric Electricity

VOLUME XVI DECEMBER, 1911 NUMBER 4

ON THE MAGNETIC FIELD OF THE EARTH.

By L. Steiner.

Dr. L. A. Bauer, in his very suggestive paper, "The external electric currents and the Earth's magnetization,"[1] has come to the following "working hypothesis:" The Earth is chiefly an electromagnet, the magnetizing currents being outside and consisting of negative electric currents circulating overhead in the same general direction as that of the Earth's rotation, namely, from west to east. In the June issue of this Journal[2] he continues the same topic and here[3] he quotes Professor August Schmidt's views concerning the same object.

As the supposition of the Earth's being an electromagnet and being magnetized by an outside primary magnetic field, if verified, would be of greatest importance in the explanation of magnetic phenomena and would—in connection with what we know about other kindred phenomena: diurnal variation, disturbances—produce a revolution in our views, the foundation of it must be carefully and thoroughly studied. I beg to make some remarks regarding that hypothesis. The importance of the question and my endeavor to avoid misunderstandings, may excuse if I treat the problem somewhat in length and often refer to things generally known.

The supposition of L. A. Bauer and that of August Schmidt do not entirely cover each other. Both suppose that the Earth, as a core, is placed in a magnetic field, which has its source outside the Earth. While, however, Bauer considers an electric current system in the upper regions of the atmosphere as the source of

[1] *Terr. Mag.*, v. xvi, pp. 33-52.
[2] *Terr. Mag.*, v. xvi, pp. 113-152.
[3] *Terr. Mag.*, v. xvi, pp. 117-119.

the primary magnetic field, Schmidt puts forward the hypothesis that from without (let us say from the Sun) lines of magnetic force are intruding. The effect upon the Earth, and consequently also the magnetic field which we observe and ascribe—in accordance with the Gaussian analysis—to inside and outside agencies, chiefly depends upon the distribution and magnitude of the magnetic permeability the lines of force meet with in their way. I will separately treat L. A. Bauer's and August Schmidt's concepts.

L. A. Bauer's Concept.

1. Let us take a sphere of homogeneous magnetization; the direction of magnetization may be AB (Fig. 1), then the magnetic potential outside the sphere will be

$$V = \frac{4}{3} R^3 \pi I \frac{\cos\theta}{r^2},$$

where I is the intensity of magnetization, R the radius of the sphere, r the distance of the point, in which the potential is V,

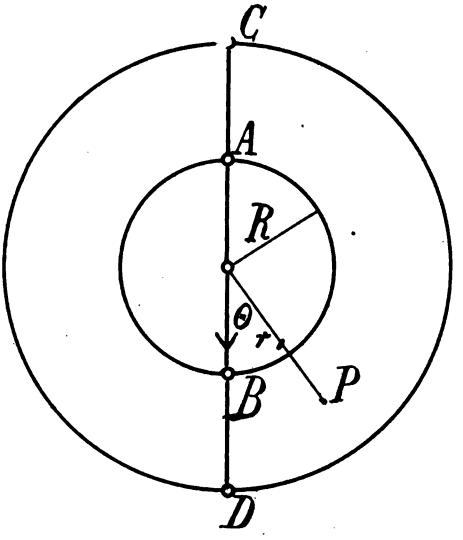

FIGURE 1.

from the center, and θ the angle reckoned from the direction AB. This expression of the potential can also be considered as the potential of a spherical surface, covered with a magnetic matter of the density $I \cos\phi$, where ϕ is again counted from AB. In the

case of the Earth A is the north magnetic pole, to which the north end (red end) of our magnets points, and AB the axis of rotation. For simplifying the research we suppose that the Earth's magnetic field is represented (as it is approximately) by a solid harmonic of the first degree and the direction of magnetization coincides with the axis of rotation.

The application of Gauss' theory leads to the result that both the internal and the external agencies have their north magnetic pole in the northern hemisphere, not far from each other (in 31°.9 angular distance[4]). For simplicity's sake we will assume that the north and south magnetic poles of the external agencies are respectively in C and D, which are on the spherical surface CD concentric with AB. The action of the external agents will be equal to that of the spherical surface CD, covered with a magnetic matter of surface density $I' \cos \phi$, where I' has the same meaning for the external agencies as I had for those having their seat in the interior of the Earth. According to L. A. Bauer's figures[5], we may put:

$$\frac{4}{3}\pi I = 0.32545, \text{ and } \frac{4}{3}\pi I' = 0.00242.$$

2. The magnetic field of the inner agencies—the field of a homogeneously magnetized sphere—can also be brought forward by a current system, having its seat in the interior of the Earth, the current function of which is[6]

$$\Phi = I R \cos \theta ;$$

or if N is the number of windings and γ the strength of the current:

$$\Phi = \frac{1}{2} N \gamma \cos \theta .$$

When we proceed from the point $\theta = 90°$, or $\Phi = 0$, then the direction of the currents will be from left to right, where $\Phi > 0$, and from right to left where $\Phi < 0$. Thus the direction of these currents will be from east to west, when positive or produced by posi-

[4] *Terr. Mag.*, v. xvi, p. 36.

[5] *Terr. Mag.*, v. xvi, p. 35.

[6] MAXWELL: A Treatise on Electricity and Magnetism, II, sec. 672. The Magnetic potential within Ω, without Ω', a spherical current sheet, and the current function are:

$$\Omega = -(i+1)\frac{1}{a} A \left(\frac{r}{a}\right)^i Y_i \; ; \quad \Omega' = i \frac{1}{a} A \left(\frac{a}{r}\right)^{i+1} Y_i \; ; \quad \Phi = \frac{2i+1}{4\pi} \frac{1}{a} A Y_i \; ;$$

where Y_i represents the spherical harmonic of degree i, and a the radius of the sheet.

tive particles, and from west to east when negative. These fields can not be directly produced by currents in the atmosphere, as either the horizontal force, or the vertical force belonging to this current-system, will not be in accordance with those produced by the magnetized sphere. The latter are in the directions north, east, and vertically (upwards):

$$X = +\frac{4}{3}\pi I \sin\theta, \quad Y = 0, \quad Z = +\frac{8}{3}\pi I \cos\theta .$$

a. When the current function of the atmospheric current system is

$$\Phi = -\frac{1}{2} a I \cos\theta ,$$

where a denotes the radius of the exterior current sheet, the magnetic force components are:

$$X = +\frac{4}{3}\pi I \sin\theta, \quad Y = 0, \quad Z = -\frac{4}{3}\pi I \cos\theta .$$

b. When we take for the current function:

$$\Phi = a I \cos\theta$$

then the forces will be:

$$X = -\frac{8}{3}\pi I \sin\theta, \quad Y = 0, \quad Z = +\frac{8}{3}\pi I \cos\theta .$$

The homogeneous magnetization, however, of the spherical core (the Earth) can be produced by external currents, whose direction is from east to west, when positive, and from west to east, when negative—as pointed out by Dr. L. A. Bauer. These hypothetical atmospheric currents have thus the same direction as those inside the Earth, which produce that part of the Earth's magnetic field which is ascribed to inner agencies.

3. Now let us see the direction of those atmospheric currents, the presence of which is disclosed to us by that part of the Earth's permanent magnetic field which must be ascribed to external agencies. Within the spherical surface CD, the lines of force of the magnetic matter of surface density $i \cos\phi$ are going from D to C, in the same direction must go the inner lines of force of the current-sheet, which we imagine on the spherical surface CD as substituting the action of the magnetic matter. As the variation in direction of the lines of forces of currents is continuous, therefore they must

come out from the spherical surface on the upper hemisphere, C, and enter into it in the lower hemisphere D. Looking on the current sheet from where the lines of force come out, the currents must circulate in the direction opposite to that of the hands of a watch. Thus it is obvious, that the direction of the currents in this spherical current sheet (CD) must be from west to east when positive, and the opposite when negative. The current function is

$$\Phi = -\frac{1}{2} I' a \cos\theta ,$$

where a is the radius of the sphere CD. And the potential within the spherical surface CD:

$$\Omega = +\frac{4\pi}{3} I' r \cos\theta .$$

Thus we see that the direction of those atmospheric currents, the reality of which is not doubtful, being disclosed by the external agencies of the Earth's magnetic field, is opposite to the direction of those ***hypothetical*** atmospheric currents, by the action of which, it is assumed, the Earth has become an electromagnet. Considering, therefore, the Earth's permanent magnetic field, there is no evidence at all for atmospheric currents from east to west when positive, or from west to east when negative, but a true evidence for currents in the opposite direction.

When L. A. Bauer asserts that the lines of magnetic force pertaining to the current sheet CD do not progress continuously and that "they suffer a displacement because of the change of sign in the vertical component of the force—the horizontal component varies continuously, but neither the vertical nor the total," then this assumption is in direct contradiction to what we know about current sheets. For, when the potentials without and within the current sheet are V_2 and V_1 and Φ the current function, then for points near the surface and on the surface, we have $V_2 = V_1 + 4\pi\Phi$ and[7]: "The value of the component of magnetic force normal to the sheet is continuous, being the same on both sides of the sheet. The component of the magnetic force parallel to the current-lines is also continuous, but the tangential component perpendicular to the current-lines is discontinuous at the sheet."

[7] MAXWELL, Treatise on Electricity and Magnetism, II, sec 653.

August Schmidt's Concept.

4. It may be given an outside magnetic field whose potential is: $U_i = C_i r^i Y_i$. Here r is the distance from the center of the Earth, O (Fig. 2), Y_i the surface harmonic of degree i, and C_i a constant. Let us put in that magnetic field the Earth with its atmosphere; r_1 and r_2 may denote the radii, μ_1 and μ the magnetic permeability of the Earth and of the atmosphere. These will be magnetized by induction. The potentials of the induced magnetization of the spherical core (Earth) of radius r_1 and of the spherical

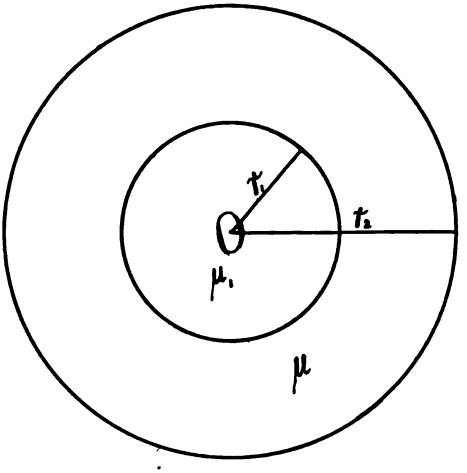

FIGURE 2.

shell (the atmosphere) of thickness $r_2 - r_1$ must satisfy the following conditions: they must be finite, must vanish at an infinite distance and satisfy Laplace's equations. Therefore they can be put in these forms[8]:

$V'_i = A_1 r^i Y_i$ the potential of the spherical shell within the shell;

$V_i = A_2 r^i Y_i + B_2 \frac{Y_i}{r^{i+1}}$ the potential of the spherical shell in the substance of the shell;

$V''_i = B_2 \frac{Y_i}{r^{i+1}}$ the potential of the spherical shell outside the shell.

$\Omega'_i = A r^i Y_i$ the potential of the spherical core inside the sphere;

$\Omega_i = B \frac{Y_i}{r^{i+1}}$ the potential of the spherical core outside the sphere.

[8] MAXWELL, *loc. cit.*, sec. 431.

These expressions must be continuous and satisfy on the surfaces the well known differential equation of continuity for the normal components of magnetic induction. So we get the equations:

$$V_i' = V_i \text{ for } r = r_1 ,$$
$$V_i = V_i'' \text{ for } r = r_2 ,$$
$$\Omega'_i = \Omega_i \text{ for } r = r_1 ,$$
$$-\mu_1 \frac{\partial (U_i + V_i + \Omega'_i)}{\partial r} + \mu \frac{\partial (U_i + V_i + \Omega_i)}{\partial r} = 0 \text{ for } r = r_1 ,$$
$$-\mu \frac{\partial (U_i + V_i + \Omega_i)}{\partial r} + \frac{\partial (U_i + V_i'' + \Omega_i)}{\partial r} = 0 \text{ for } r = r_2 .$$

The constants A_1, A_2, B_2, B_3, A, B, must be determined according to these equations.

The resultant potential outside the spherical core on its surface, will be

$$(U_i + V_i + \Omega_i)_{r=r_1} = (C_i + A_2)\, r_1^i\, Y_i + (B_2 + B) \frac{Y_i}{r_1^{i+1}} .$$

In the Gaussian analysis we ascribe the potentials of the form $r^i Y_i$ to outside agents, those of the form Y_i / r^{i+1} to inner agents. Thus we have:

$$\frac{\text{Potential of exterior agents}}{\text{Potential of interior agents}} = \chi = \frac{C_i + A_2}{B_2 + B} r_1^{2i+1} .$$

For the determination of the six constants we only have five equations, but we shall see that when five of them are expressed by the sixth (f. i. by B), then the coefficient of the latter in the expression for χ will vanish. We have:

$$A_1 = A_2 + B_2 \frac{1}{r_1^{2i+1}} ,$$
$$B_3 = A_2\, r_2^{2i+1} + B_2 ,$$
$$A = B \frac{1}{r_1^{2i+1}} ,$$
$$a A_2 + b B_2 = c - b B ,$$
$$a' A_2 + b' B_2 = c' - b' B ,$$

where

$$a = (\mu_1 - \mu)\, i\, r_1^{2i+1} ,$$
$$b = \mu_1 i + \mu (i + 1) ,$$
$$c = -(\mu_1 - \mu)\, i\, C_i\, r_1^{2i+1} ,$$
$$a' = -[\mu i + i + 1]\, r_2^{2i+1} ,$$
$$b' = (i + 1)(\mu - 1) ,$$
$$c' = (\mu - 1)\, i\, C_i\, r_2^{2i+1} .$$

Resolving the equations, we get

$$\chi = \frac{C_i (a b' - a' b) + c b' - c' b}{a c' - a' c} r_1^{2i+1} .$$

where

$$C_i(a\,b' - a'\,b) + c\,b' - c'\,b = (2\,i+1)\,[\mu_1\,i + \mu\,(i+1)]\,C_i r_2^{2i+1},$$
$$a\,c' - a'\,c = -(2\,i+1)\,i\,(\mu_1 - \mu)\,C_i r_1^{2i+1} r_2^{2i+1}$$
$$\text{and } \chi = -\frac{\mu_1\,i + \mu\,(i+1)}{(\mu_1 - \mu)\,i}.$$

We get the same result when we start from the formulæ of Maxwell[8] for a spherical shell, and then placing the spherical core in this shell, we change the constants in such manner that the new conditions, introduced by the spherical core, may be fulfilled.

Since $\mu_1 > \mu$, we conclude first, that the potentials of the exterior and the interior agents must be of opposite sign; second, the potential of exterior agents must be greater than that of the interior agents. The results of the analysis of the Earth's permanent magnetic field contradict both these conclusions. The potential of the agents outside the Earth is the 1-135th part of that of the agents inside and they are of the same sign, (for $i = 1$).

5. The objection we made to L. A. Bauer's concept is nothing else, than in simpler form what we proved here regarding the sign of the two potentials. That the sign must be opposite for the potentials of exterior and interior agents, when the Earth is to be considered as an electromagnet, we can see from the following simple consideration:

The current function of a spherical current sheet may be put in the form[9]:

$$\Phi = \frac{2i+1}{4\pi}\frac{A}{a}\,Y_i.$$

When proceeding on the exterior surface of a sphere on whatever line, but in such direction that Φ is increasing, then the current has the direction from left to right. The potentials within and without the sheet are:

$$\Omega = -(i+1)\frac{A}{a}\left(\frac{r}{a}\right)^i Y_i \text{ and } \Omega' = i\frac{A}{a}\left(\frac{a}{r}\right)^{i+1} Y_i,$$

where Y_i represents the spherical harmonic of degree i, a the radius of the sheet, A a constant and r the distance from the center of the sphere. And we have the relation:

$$\Omega' = \Omega + 4\pi\Phi \text{ for } r = a.$$

We see that when Y_i is the same, then Φ and Ω are of opposite sign.

Now, according to the observational data (supposing $i = 1$) we have plus (+) sign for Ω in the lower (D) hemisphere (Fig. 1), therefore such conditions as represented in Fig. 3, and thus currents on the sphere of radius a from west to east when positive,

[9] MAXWELL, *loc. cit.*, sec. 672.

as we found in 3. The conditions for the supposition of L. A. Bauer would be as in Fig. 4. The currents would go from east

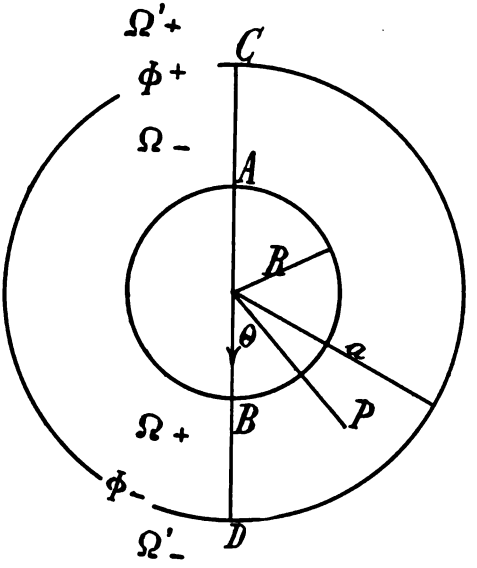

FIGURE 3.

to west when positive, the lines of magnetic force of the current sheet from *C* to *D* and thus magnetizing the spherical core in the direction *AB*.

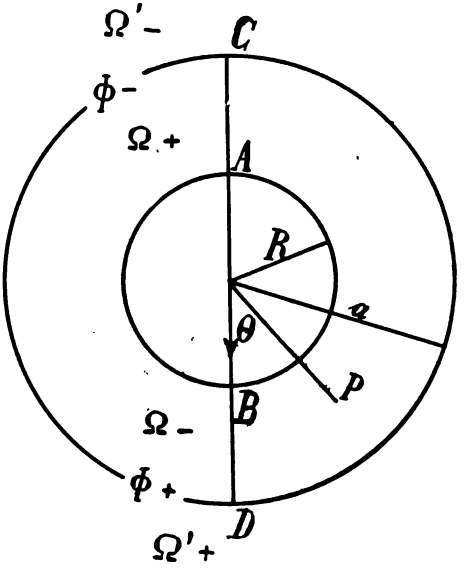

FIGURE 4.

As the potential of the agents, having their seat inside the Earth, (V), is of plus sign in the lower and minus sign in the upper hemisphere (Fig. 1, $i = 1$), we see that in the actual case V (the potential of interior agents) and Ω (potential of exterior agents) are of the same sign, while the concept of L. A. Bauer leads to the conclusion that V and Ω are of opposite sign.

The conclusion regarding the ratio of the values of the potentials holds good naturally against the concept of L. A. Bauer, too.

Some general remarks.

6. The important question arises, how far we are justified to apply the above results to a revolving Earth.

As long as we do not assume that the process of magnetization by induction—as such—is subject to other laws, when a large body *revolves*—and this, for aught I know, is not experimentally proved—the only cause which can produce a considerable change in the results arrived at above and modify the distribution of the induced magnetization, is induced currents.[10] The induced currents, however, which are connected with the daily rotation of the Earth around its axis, contribute only to the daily variation of terrestrial magnetism, and this variation—of very small amount in comparison with the permanent field, and subject to a period of one day—does not enter into the consideration of the permanent field.

7. According to the Gaussian theory the Earth can in first rough approximation be considered as a homogeneously magnetized sphere (magnetized in the direction of the axis of rotation), whose magnetization is $I = 0.077$. Were it really so, then magnetic measurements in the Earth (for instance in mines)—as far as local magnetic disturbances are not present—would give a force which would partly depend on the geometrical form of the cavity where we make the measurement (supposing naturally that the hollowing out of the cavity does not alter the lines of magnetic induction). If the form of the cavity is a cylinder, the axis of which is parallel to the direction of the magnetization and whose diameter is great to the axis, we should get the magnetic induction $\frac{8}{3}\pi I$, the components of which in the horizontal (directed to north) and vertical direction (directed upwards), are

$$-\frac{8}{3}\pi I \sin\theta \text{ and } \frac{8}{3}\pi I \cos\theta ,$$

where θ is counted, as above, from the south pole. As the components of the force, measured above the Earth's surface, are $\frac{4}{3}\pi I \sin\theta$ and $\frac{8}{3}\pi I \cos\theta$, we see that in the horizontal force we should have a discontinuity both regarding the direction and the

[10] HORACE LAMB: On electrical motions in a spherical conductor. Phil. Trans. 1883, pp. 519 *et seq.*, especially p. 543.

value of the horizontal component, and the vertical force would not be altered. This, in reality, is not the case. Magnetic measurements in hollows do not show any considerable change of the components (as far as local disturbances are avoided). Further, the upper parts of the Earth's crust show—in general—very weak magnetization. We conclude that the Earth, as a whole, can not be considered as a homogeneously magnetized sphere.

The expression of the potential for points without the sphere is formally the same for a small magnet placed in the center of the Earth, whose magnetic moment is $M = \frac{4}{3}\pi R^3 I$ and its direction coincides with the direction of magnetization of the sphere. We obtain also similar formulæ for a homogeneously magnetized spherical core, which is surrounded by a magnetizable spherical shell. The more general case of a spherical current sheet in the Earth's crust surrounded by a spherical shell of magnetic permeability μ, leads to similar results. The current function may be:

$$\Phi = -\frac{1}{4\pi}\frac{2i+1}{i+1} a_1^i C_i Y_i,$$

where Y_i denotes the spherical harmonic of degree i, C_i is a constant, and a_1 the radius of the spherical current sheet. Further,[11]

$$\Omega = C_i r^i Y_i \text{ and } \Omega' = -\frac{i}{i+1} a_1^{2i+1} C_i r^{-(i+1)} Y_i$$

are the magnetic potentials of the current sheet within and without the spherical surface. The radii of the magnetic shell may be a_1 and a_2 $(a_1 < a_2)$; the magnetic potential of the shell can be written:

$\Omega_1 = A_1 r^i Y_i$ within the shell;
$\Omega_2 = A_2 r^i Y_i + B_2 r^{-(i+1)} Y_i$ in the substance of the shell;
$\Omega_3 = B_3 r^{-(i+1)} Y_i$ without the shell.

In order to determine the coefficients A_1, A_2, B_2, B_3, we have the equations:

$$\Omega_1 = \Omega_2 \text{ for } r = a_1, \quad (1)$$

$$\Omega_2 = \Omega_3 \text{ for } r = a_2, \quad (2)$$

$$-\frac{\partial(\Omega + \Omega_1)}{\partial r} + \mu\frac{\partial(\Omega' + \Omega_2)}{\partial r} = 0 \text{ for } r = a_1, \quad (3)$$

$$-\mu\frac{\partial(\Omega' + \Omega_2)}{\partial r} + \frac{\partial\Omega' + \Omega_3)}{\partial r} = 0 \text{ for } r = a_2. \quad (4)$$

Here we supposed that within the current sheet and without the spherical shell the magnetic permeability is 1. We obtain:

$$A_1 = \frac{i(\mu-1)(\mu i + i + 1)}{N}\left[1 - \left(\frac{a_1}{a_2}\right)^{2i+1}\right] C_i;$$

$$A_2 = -\frac{i(2i+1)(\mu-1)}{N}\left(\frac{a_1}{a_2}\right)^{2i+1} C_i;$$

[11] MAXWELL, *loc. cit.*, II, sec. 672.

$$B_i = \frac{i(\mu-1)}{N} a_1^{2i+1}\left[(\mu i + i + 1) - i(\mu-1)\left(\frac{a_1}{a_2}\right)^{2i+1}\right] C_i ;$$

$$B_e = \frac{i^2(\mu-1)^2}{N} a_1^{2i+1}\left[1 - \left(\frac{a_1}{a_2}\right)^{2i+1}\right] C_i ;$$

where $N = [\mu(i+1)+i][\mu i + i + 1] - i(i+1)(\mu-1)^2\left(\frac{a_1}{a_2}\right)^{2i+1} > 0.$

The potential without the shell will be $\Omega' + \Omega_2$, and the components of magnetic force $-\frac{\partial(\Omega'+\Omega_2)}{r\partial\theta}$ and $-\frac{\partial(\Omega'+\Omega_2)}{\partial r}$. The potential in the substance of the shell is $\Omega' + \Omega_2$, and the components of magnetic induction $-\mu\frac{\partial(\Omega'+\Omega_2)}{r\partial\theta}$ and $-\mu\frac{\partial(\Omega'+\Omega_2)}{\partial r}$. The vertical component remains unchanged, when we go from without the shell into the substance of it. This is expressed by the equation 4, but can also be verified from our formulæ. The horizontal component varies in the proportion 1: μ without change of direction, as it can easily be shown from our expressions. Since the magnetic permeability of the Earth's crust is, on the average, very near to 1[12], we can not expect to detect this abrupt change, and this the less as in many cases it will be covered by local disturbances.

What we called I, the intensity of magnetization of the homogeneously magnetized sphere of radius $R = a_2$, will be ($i = 1$):

$$I = \frac{3}{4\pi}\left(\frac{a_1}{a_2}\right)^3 C_i \left\{-\frac{1}{2} + \frac{(\mu-1)^2\left[1-\left(\frac{a_1}{a_2}\right)^3\right]}{(2\mu+1)(\mu+2) - 2(\mu-1)^2\left(\frac{a_1}{a_2}\right)^3}\right\}$$

Assuming layers of different magnetic permeability, we should get similar formulæ.

From measurements on the surface we, of course, can not get enlightenment about the distribution of magnetic matter (or electric currents) in the crust. Different assumptions will conduce to the same mathematical expression, but not all assumptions will be equally probable in physical sense. Each term of the Gaussian development (for the agents inside) can be considered as produced by a deep-seated system of electric currents (or of magnetic matter), which is surrounded by layers of different magnetic permeability. As to the law, according to which the magnetic permeability varies, we are led to more or less probable conjectures much like to the considerations we make about the distribution of density within the Earth's crust.

Budapest.

[12] Röcker & Thorpe, Survey of the British Isles for the Epoch, January 1, 1891, p. 641.

THE PHYSICAL THEORY OF THE EARTH'S MAGNETIC AND ELECTRIC PHENOMENA. No. IV.

(Continued)

By L. A. Bauer.

Preliminary Remarks on Steiner's Article.[1]

53. I am grateful to Dr. Steiner for his helpful discussion of the question raised in Nos. III and IV as to whether the Earth is chiefly an electromagnet, due possibly to negative electric currents circulating overhead in the same general direction as that of the Earth's rotation. It may be recalled that this was advanced merely as a *working hypothesis* in order to ascertain just what conclusions would thereby be implied and how far the hypothesis might assist in explaining the phenomena found in my paper, PD No. II. (*Terr. Mag.* v. 6, pp. 13-24). The facts of the latter paper will receive fuller treatment in a subsequent number; they appear to be related in some manner to the Earth's rotation.

Steiner agrees with me that the portion of the Earth's magnetism which heretofore was thought almost universally could only be due to internal agencies, can be produced, at least theoretically, equally as well by *external* electric currents. He is also in agreement with me as to the direction in which these external currents would have to circulate around the Earth, viz., from west to east, if negative, and the reverse, if positive. In other words, the direction of the external currents would be precisely the same as that of internal currents supposed capable of causing the Earth's magnetism. If Nos. III and IV accomplish nothing beyond the general recognition of these two facts—that the electric currents may be external ones, and that their direction may be at the same time the same as the supposed internal ones—I shall feel abundantly repaid for the labor bestowed. Given the possibility of an external source, a variety of questions stimulating further research immediately arises. Thus one valued correspondent writes:

"Some three years or so ago, in the course of my atmospheric studies, I ran onto a line that I thought promised some light on terrestrial magnetism, but it ran counter to the Gaussian deduc-

[1] These remarks on a first draft of a paper which he had withheld from publication, were submitted to Dr. Steiner. I am glad to find, upon my return to Washington, that he has decided to publish his results (*Terr. Mag.* v. 16, pp. 221-232), and has at the same time, in his more complete paper, touched upon some of the questions raised by me.—*Washington, Dec. 24, 1911.*

tion that the magnetism was mainly due to *internal* agencies, and so I laid the matter on the shelf. Your present view makes it look as if this were worth following up, and I purpose to do, indeed, am doing, so. So far as I now see it will fall in happily with your view as recently expressed."

The next question raised by Steiner is: Have we any observational evidence of the existence of such external currents as would be required? I endeavored to show in my paper that the results of the analyses of the Earth's total magnetization revealed a weak outside magnetic field, whose magnetic axis was pointed in the same general direction as that of the Earth's internal magnetization. And, according to my interpretation, the upper electric currents which could produce the revealed outside magnetic field would have to circulate from west to east, if negative, hence in the same direction as the currents required for producing the magnetization "of the spherical core (the Earth)." He, however, reaches a diametrically opposite conclusion—he gets *positive* currents going from west to east.

It seems to me that, as you break through the bounding surface enclosing the magnetizing agencies, the lines of force, when passing from a point below this surface to a point above, do not progress continuously, but suffer a displacement because of the change of sign in the vertical component of the force. The horizontal component varies continuously, but neither the vertical nor the total. The result is that, though for the outside magnetic potential, the lines of magnetic force between the Earth's surface and the supposed upper bounding surface proceed at the North Pole upwards, as the author rightly assumes, when the upper surface is reached and penetrated they do not continue in their uninterrupted course, owing to the angular displacement suffered, but are made to swing around; consequently, instead of emerging from the supposed surface, they actually re-enter the surface. Reference to Figure 1, and formulæ, sections 30 and 31 (*Terr. Mag.*, v. 16, pp. 39-42), will help to make the contention clear.

Perhaps it will help also to bear this fact in mind: The results derived from the application of the Gaussian analysis to the Earth's magnetic phenomena must be interpreted in accordance with the properties of the magnetic systems implied in the Gaussian formula. Starting thus, it follows that the vertical component will not be continuous, as the surface enclosing the systems is broken through. It is not contended here that the application of the Gaussian

form of analysis is wholly correct; the purpose has been to show what follows with this customary form of procedure. The direction of the external negative currents which could produce the kind of magnetic system disclosed by magnetic needles on the Earth's surface appears to me to depend wholly upon the settlement of this point.

Steiner next examines into the question as to the magnetic permeability required for the Earth, if it be an electromagnet in the manner supposed, and he reaches certain well-known conclusions respecting induction in spherical bodies. I am in full agreement with him as to the difficulties here presented, and I recognize that the tenability of the hypothesis that the Earth is an electromagnet will, in no small measure, rest upon the values which result for the Earth's magnetic permeability. The magnetic permeability of surface rocks is not much over unity; let it not be forgotten, however, that by judging simply from surface magnetizations one would hardly conclude that the Earth is magnetized to the extent that it actually appears to be. Similarly it would not be safe to gauge the Earth's magnetic permeability merely by surface values.

How far the theoretical conclusions respecting induction in spherical bodies are strictly applicable to the case at hand, remembering that we are dealing with a *revolving* Earth, I am not at present in a position to say. It might be mentioned, however, that the hypothesis that the Earth, as a first approximation, can be treated as a homogeneously magnetized sphere may have to be considered as more or less mathematical fiction. See PD No. II (*Terr. Mag.*, v. 6, pp. 13-24). It is shown there that the supposed homogeneous magnetization varies from parallel to parallel. Only to the extent of about 65 to 70 per cent can the observed magnetic forces be represented *mathematically* by a simple magnetization. Were it possible to define any portion of the Earth in which the same homogeneous magnetization prevails throughout, the probabilities are that the bounding surface would not be that of a sphere. And, according to a well-known fact, a slight departure in the shape of the induced body from that of a sphere has a comparatively large effect upon the induction and permeability.[2] There is also no telling what the effect of the errors larger than anticipated, which we are finding in the existing magnetic charts, will have upon the constants defining the characteristics of the internal and external magnetic fields.

[2] *cf.* J. A. EWING'S Magnetic Induction in Iron and other Metals, sec. 29.

Since Steiner also investigates Professor August Schmidt's concept set forth in the copious extracts found in section 48, it is but fair to Schmidt that his latest views, communicated to me under date of March 31st last, be given here:

"Wenn ich heute meine Anschauungen von vor 16 Jahren wieder prüfe, so glaube ich, in der Hauptsache Recht behalten zu müssen, nämlich darin, dass aller Magnetismus, der von Gauss inneren Ursachen zugeschrieben wird, durch ein kosmisches auf der Elliptik senkrecht stehendes Magnetfeld erzeugt werde, dem die für magnetische Kraftlinien einen sehr kleinen Widerstand bildenden inneren Planetenmassen als *Anker* dienen.

"Im Einzelnen aber halte ich die Hypothese für fähig, verändert und verbessert zu werden. Einmal wird man nach den heutigen Anschauungen bei derselben Rotationsrichtung kosmischer Substanzen zwischen positiven und negativen elektrischen Ladungen solcher Substanzen unterscheiden müssen. Auch meine Annahme, dass ähnlich der Erde auch die andere Planeten und die Sonne als "Anker" der kosmischen Kraftlinien wirken, erscheint betreffs der Sonne sehr anfechtbar. Ein geschlossener Kreisstrom wird die magnetisch gut permeable Masse *I* im Innern des Kreises nicht wie eine ausserhalb liegende Masse *E* zum *Anker* machen, sondern zum *Elektromagnet;* die Erdatmosphäre, der Mond sowie alle mit ihren Bahnen die Erdbahn umschliessenden planetarischen Massen werden Wirkungen haben, denen unsere Erdmagnetiker einen ausserhalb der Erde liegenden Sitz zuschreiben; die Sonne aber durch ihre Rotation und alle innerhalb der Erdbahn umlaufenden Substanzen dürften die Wirkungen haben, denen Gauss einen Sitz der Ursache im Erdinnern zuschreibt. Für die so veränderte Hypothese wird die Sonne ein mächtiger Elektromagnet mit einer der Erde entgegengesetzten Polarität.

"Noch anders müsste die magnetische Oekonomie des Sonnensystems gedacht werden, wenn die Untersuchungen über Planetenmagnetismus von Leyst sich bestätigen würden, nach welchen die Planeten der Reihe nach entgegengesetzte Richtungen der magnetischen Axen zu haben scheinen."

It is not possible for me at present to enter into a fuller examination of Steiner's results. Instead I shall have to content myself with the above preliminary remarks, reserving for a future occasion the discussion on the applicability of his results to the particular case in hand.

On board the Carnegie,
Mauritius, August 6, 1911.

ATMOSPHERIC ELECTRICITY OBSERVATIONS ON THE SECOND CRUISE OF THE "*CARNEGIE*," FROM NEW YORK TO COLOMBO.

By Edward Kidson.

I. Specific Conductivity of the Atmosphere.

The observations were taken with a Gerdien conductivity apparatus, using the same methods as those employed on the first cruise of the *Carnegie*, as previously described in this Journal.[1] The observations were also taken in the same position as on the first cruise. The aluminum leaf electroscope of the Gerdien apparatus was replaced by a string electrometer of the form described by Lutz.[2] This instrument proved very satisfactory, as the reading was not seriously interfered with by the rolling of the ship. The electrometer was frequently calibrated by means of batteries of small Weston cells. The sensibility varied somewhat, but the calibration curves were always of the same form. The number of observations obtained is not sufficient in the various conditions of humidity, cloud, pressure, geographical position, nearness of land, etc., to draw many general conclusions. When a much larger number of observations has been secured, however, it is probable that valuable information will result.

Taken as a whole, the conductivity observations so far obtained by the Department of Terrestrial Magnetism seem to indicate a diminution in the conductivity in equatorial regions, and, at any rate during the day time, in the near neighborhood of land. At the same time the ratio, q, of the conductivity for positive electricity to that for negative, becomes smaller. These are perhaps regions of upward currents. The results of the observations are given in Table I.

On August 29 and November 7, 1910, continuous observations were taken over twenty-four hours. On August 4 no definite results were shown, the conductivity varying irregularly. The conditions were abnormal. On November 7, in the "Doldrums," the conductivity was practically constant throughout, and there was little difference between that for negative and that for positive electricity.

[1] June, 1910.

[2] *Physik. Zs.*, v. 9, No. 3, pp. 100–107.

TABLE I.

Conductivity Observations on the Second Cruise of the Carnegie

Date	Latitude	Longitude	Ship's Time	Duration	No. of Obs'ns	$\lambda_p \times 10^4$	$\lambda_n \times 10^4$	$\lambda \times 10^4$	$\frac{\lambda_p}{\lambda_n}$	Temp. C.	Barometer	Relative Humidity	Wind	Sea	Weather	Remarks
1910	°	°	h	h m							mm	%				
July 5	38.2N	56.6W	11.0	0 32	4	2.31	1.91	4.22	1.21	24	760	91	SWxW.6	M	m	Hazy. In gulf stream.
12	34.8N	46.7W	10.4	1 55	10	1.52	0.91	2.43	1.67	24	766	68	WxS.0—2	S	b	Clear day—almost calm—very smooth.
19	23.4N	50.6W	10.8	2 15	8	1.10	0.99	2.09	1.11	26	765	77	E.5	M	b	In N. E. Trade area.
23	18.8N	62.0W	9.8	0 55	8	2.66	2.33	4.99	1.14	27	762	72	ENE.5	M	bm	Fine & sunny-haze low down—in N. E. Trade.
Aug. 23	32.7N	61.7W	9.7	1 17	8	2.33	1.67	4.00	1.40	28	768	73	SE.5	M	b	In N. E. Trade—fine day—little swell.
26	32.9N	56.1W	9.7	1 16	8	2.75	2.52	5.27	1.09	26	763	71	NE.4	M	cm	Hazy—weak sunshine.
27	32.4N	55.0W	9.9	1 23	8	3.58	3.09	6.67	1.16	27	762	78	Var. 0—1	S	bcq	In calm belt.
29	32.5N	54 W	....	25 00	141	2.75	2.29	5.04	1.20	26	763	67	Calm	S	bc	Continuous obs'ns over whole day.
30	32.1N	53 W								28	765	74				Sky generally clear—light airs at times from N. qtr.
Sept. 5	22.0N	44.4W	10.8	0 26	4	2.63	1.72	4.35	1.53	26	763	82	ExS.4	M	b	In Trade wind—sunny.
10	12.2N	39.4W	10.3	0 56	8	1.91	1.75	3.66	1.09	27	759	80	ExS.4	M	b	" " " "
12	9.2N	38.4W	10.5	0 58	8	2.55	2.60	5.15	0.98	27	757	75	W.0—1	M	b	Almost calm—in doldrums.
13	8.1N	37.5W	10.4	0 49	8	2.22	2.16	4.38	1.03	26	757	75	W.0—1	M	b	" " " "
14	7.2N	36.9W	10.0	1 32	10	1.56	1.22	2.78	1.28	26	758	78	SE.0—1	M	bcq	" " " "
18	5.6N	35.8W	10.6	0 48	5	2.31	1.68	3.99	1.38	28	758	76	SExS.4	M	cqp	In edge of S. E. Trade.
21	0.8N	43.0W	10.7	0 37	6	1.31	1.26	2.57	1.04	28	758	70	SE.4	M	b	Sunny—in S. E. Trade.
Oct. 17	0.9N	48.1W	9.6	2 18	10	2.11	1.63	3.74	1.30	27	758	74	ExN.4	S	bc	Off coast South Am.—mouth of Amazon.
20	6.8N	48.7W	9.4	1 22	10	2.84	3.43	6.27	0.83	25	756	88	SE.1	M	cq	In doldrums — just after long drizzle.
22	7.4N	45.9W	10.3	1 25	8	2.26	1.74	4.00	1.30	28	757	81	SExS.3	M	bcq	On edge of S. E. Trade.
25	13.1N	45.6W	10.0	1 53	10	2.16	1.70	3.86	1.29	27	759	82	ESE.4	M	bc	
28	17.5N	42.9W	10.4	1 06	10	2.97	2.08	5.05	1.43	26	761	83	E.5	M	bcq	Very light drizzle from high cloud part of time.
Nov. 5	11.0N	37.0W	13.6	1 00	10	1.75	1.14	2.89	1.54	27	760	83	ESE.3	S	bc	Sunny—on edge of N. E. T'de.
7	11.7N	36.0W	....	24 14	166	1.73	1.69	3.42	1.02	26	758	70	Calm	L	b	Sunny—in doldrums—very light airs from N. E. during latter half.
8	11.8N	36.0W	....	.....	....	....	....	....	....	30	759	88	.....	....	.....	
11	8.3N	34.1W	9.9	1 25	10	1.74	1.18	2.92	1.47	27	758	86	ExS.4	MR	bc	Squally—in doldrums.
13	6.8N	33.4W	10.4	0 36	6	1.42	1.41	2.83	1.01	26	757	88	SExE.0—4	M	ocq	" " "
15	3.9N	32.1W	9.7	1 23	10	1.96	1.29	3.25	1.52	25	758	90	SE.3—4	M	cq	Clearing up after heavy rain squalls—weak sun through scud.
22	7.7S	34.6W	10.4	0 29	5	2.68	1.76	4.44	1.58	27	759	81	SExS.4	M	bc	Coast of S. America, near Parahiba, in sight.
23	9.9 S	34.6W	12.5	2 23	10	2.59	1.75	4.34	1.48	27	759	86	ESE.4	M	bc	In S. E. Trade.
30	22.4 S	39.0W	10.0	1 57	8	2.39	2.13	4.52	1.12	22	760	85	SSW.6	MR	bc	Sunny—blowing half gale—sea fairly rough.
Dec. 2	23.2 S	42.6W	10.4	0 34	5	2.18	1.60	3.78	1.36	23	...	84	ESE.0—1	L	bc	Sunny—almost becalmed off Rio de Janeiro.

TABLE I—CONTINUED.

Conductivity Observations on the Second Cruise of the Carnegie

Date	Latitude	Longitude	Ship's Time	Duration	No. of Obs'ns	$\lambda_p \times 10^4$	$\lambda_n \times 10^4$	$\lambda \times 10^4$	λ_p/λ_n	Temp. C.	Barometer	Relative Humidity	Wind	Sea	Weather	Remarks
1911	°	°	h	h m							mm	%				
Jan. 2	26.6 S	41.1W	10.7	1 17	10	2.39	2.10	4.49	1.14	23	756	81	WSW.3	M	bc	
6	30.8 S	45.5W	11.6	0 36	6	2.52	1.98	4.50	1.27	22	756	86	WSW.5	M	b	Fine and sunny.
7	30.5 S	47.1W	10.9	1 01	10	2.87	2.61	5.48	1.10	23	759	76	SW.3	M	bc	
13	35.0 S	54.3W	13.9	1 17	10	1.53	1.21	2.74	1.26	22	751	93	SW.2	M	o	At mouth of River Plate.
Feb. 16	35.2 S	56.8W	10.2	1 16	8	1.97	1.86	3.83	1.06	17	767	68	SE.5	S	c	In River Plate.
19	34.9 S	56.5W	10.4	1 31	10	2.16	1.80	3.96	1.20	18	765	75	SE.5	S	bc	Off Montevideo.
21	35.6 S	55.9W	9.4	1 16	10	2.87	2.69	5.56	1.07	20	763	68	NE.3	S	c	At mouth of Plate.
25	36.5 S	50.4W	11.5	0 36	6	1.44	1.56	3.00	0.92	20	762	89	NNE.2	S	b	
27	38.4 S	45.0W	9.6	1 59	14	1.96	1.65	3.61	1.19	19	767	90	NE.5—6	M	o	Clearing up slowly—a little spray flying.
28	39.2 S	41.0W	11.3	0 18	3	1.98	1.65	3.63	1.20	19	762	84	NNE.6—7	R	b-c	Low scud—spray flying.
Mar. 2	39.7 S	35.5W	13.4	0 32	6	3.48	2.99	6.47	1.16	15	765	73	SSW.7	R	b-c	Spray flying—rain squalls a. m.
7	41.3 S	18.5W	9.0	0 25	4	2.68	1.62	4.30	1.65	15	757	100	N.5	R	f	Wetting fog—probably helped discharge mechanically.
9	41.2 S	12 W	9.8	1 35	6	0.99	0.51	1.50	1.94	15	764	99	N.4	M	f	Thick fog.
13	39.5 S	0.6 E	10.2	1 06	8	1.90	0.96	2.86	1.98	13	774	73	WSW.2	M	c	
16	38.5 S	7.2 E	10.5	1 16	10	2.80	2.23	5.03	1.26	16	769	76	N.3	S	b	Very fine and clear—sea very smooth.
18	37.0 S	11.7 E	10.0	1 23	8	2.19	1.80	3.99	1.22	18	762	71	WNW.3	M	bc	
19	35.1 S	15.5 E	9.3	0 35	6	2.23	2.18	4.41	1.02	17	764	87	SSW.6	M	o	A little fine spray flying—fan not rotated by hand.
Apr. 28	38.7 S	27.0 E	9.7	1 20	10	2.43	2.28	4.71	1.07	19	760	78	W.6	R	bc	Gradually clearing up.
May 3	39.8 S	38.3 E	9.9	1 35	10	2.60	2.37	4.97	1.09	12	760	72	Calm	S	bc	Gradually clouded up—moderate swell.
4	40.2 S	41.4 E	9.7	1 42	10	2.87	2.89	5.76	0.99	10	756	87	SSW.6	M	o	High wind—A little spray flying.
10	40.3 S	62.3 E	9.4	1 12	9	1.83	2.07	3.90	0.88	15	769	74	NNW.4	M	bc	Smoke from galley interfered somewhat. " " " "
11	40.3 S	67.1 E	9.5	1 54	10	3.28	2.30	5.58	1.43	14	763	84	WNW.7	M	bcq	
12	39.8 S	70.8 E	9.2	0 30	5	3.08	2.63	5.71	1.17	11	770	97	S.4	M	oqm	Interrupted by rain squalls.
14	39.4 S	73.5 E	9.2	1 24	10	3.20	2.93	6.13	1.09	14	766	86	ENE. 0—2	S	c	
15	40.0 S	74.4 E	9.7	1 22	10	2.34	1.87	4.21	1.25	14	763	89	SE.4	S	cq	Sun shining.
17	38.6 S	77.0 E	9.1	1 38	10	3.19	3.11	6.30	1.03	13	764	94	SW.3	S	b	Near St. Paul Is.
19	35.6 S	77.6 E	9.2	1 20	10	2.53	2.23	4.76	1.13	15	767	84	SSW.3	M	o	
22	28.5 S	76.9 E	9.6	1 22	10	3.10	2.75	5.85	1.13	20	766	79	E.5	M	b	Probably in Trade wind.
23	26.0 S	76.4 E	9.3	1 24	10	4.40	3.29	7.69	1.34	21	763	91	ESE.6	M	o	Sea rising.
24	23.9 S	76.4 E	10.0	1 13	8	4.29	4.45	8.70	1.97	22	761	84	SExE.5	M	cq	In S. E. trades—spray flying.
25	21.1 S	76.5 E	9.5	1 17	10	4.27	4.24	8.51	1.01	26	760	89	SE.4	M	b	Fine weather—in S. E. tr'de.
27	18.3 S	76.4 E	12.5	8 04	50	3.21	3.21	6.42	1.00	25–26	760–759	78–81	SW-S. 1–4	S–M	bcq	Fine day with passing showers.

II. Radioactivity Observations.

These also were similar to those of the first cruise. A fine bare copper wire was hung in the rigging and exposed at a high negative potential and afterwards tested for radioactivity. The amount of activity obtained varied in a very irregular manner, but very little activity was shown in mid-ocean. Great difficulty was experienced in maintaining a sufficiently high potential on the collecting wire with a Zamboni pile. In fact, the latter was only satisfactory in the tropics and during the first part of the cruise. The activity is measured by the number of volts the charge on the electrometer falls owing to the radioactivity in one hour, beginning fifteen minutes after discharging the wire. During the first part of the cruise the testing apparatus was that used on the previous cruise; later a vessel made by the Department, with a discharging cylinder attached to the string electrometer, was used. The dimensions and capacities of the two forms of apparatus would not differ greatly. The results are shown in Table II.

III. Potential Gradient of the Atmosphere.

The method of observation used was to fix a radium collector to the end of a bamboo rod projecting about 3.6 meters out from the stern of the ship and about 1.1 meters from the midships line. The collector was connected to the testing electrometer, which was clamped to the taffrail. In this way the necessary insulation was reduced to a minimum. The apparatus was so designed that the bamboo rods could be swung in while the collector was being mounted. The idea at first was to use two rods, one above the other, with a collector on each, and to measure the potential difference between them. No measurable difference could be observed, however, and it became apparent that the equipotential surfaces were practically vertical round the stern of the vessel. If one collector were nearer the ship than the other a potential difference appeared. The height of the collector ranged from three to four meters above the sea surface. The potential shown by the electrometer oscillated rapidly with the rise and fall and roll of the vessel. The potential gradients obtained are, of course, only relative. Standardizing experiments will, however, be carried out in the future.

The following table gives a list of the results obtained. Most of the observations just preceded or followed conductivity observa-

TABLE II.

Radioactivity Observations on the Second Cruise of the Carnegie.

Date	Latitude	Longitude	Activity	Length of Wire	Apparatus used
1910	°	°		Meters	
July 7	38.0N	50.6W	trace	7	Elster and Geitel
11	35.6N	47.0W	...	7	" " "
13	33.9N	46.0W	trace	7	" " "
15	31.1N	46.0W	....	7	" " "
21	20.4N	56.1W	trace	7	" " "
Aug. 22	30.4N	63.3W	trace	7	" " "
24	33.2N	61.3W	16	16	" " "
28	32.5N	54.3W	8	16	" " "
Sept. 3	26.2N	46.0W	10	16	" " "
11	10.5N	39.1W	18	16	" " "
17	5.9N	35.9W	10	7	" " "
22	0.0	45.8W	5	16	" " "
Oct. 21	6.0N	47.5W	15	16	" " "
24	12.0N	45.7W	29	16	" " "
26	15.3N	44.4W	58	16	" " "
29	15.4N	41.8W	11	16	" " "
Nov. 3	11.8N	37.9W	15	16	Department's
4	12.5N	37.5W	10	16	"
6	11.1N	36.6W	31	16	"
10	10.2N	34.9W	10	16	"
16	3.4N	32.0W	17	16	"
21	6.0S	34.4W	....	16	"
26	17.7S	36.8W	....	16	"
Dec. 1	23.0S	40.6W	4	16	"
1911					
Jan. 3	26.9S	42.4W	6	16	"
10	31.5S	47.8W	95	16	"
10	31.5S	47.8W	12	16	"
10	31.5S	47.8W	9	16	"
11	33.3S	49.2W	12	16	"
Feb. 18	34.9S	56.5W	55	16	"
20	35.0S	56.6W	trace	16	"
22	36.3S	54.2W	96	16	"
24	36.1S	51.8W	trace	16	"
Mar. 4	40.4S	28.5W	....	16	"
14	39.4S	1.3E	4*	16	"
17	37.9S	9.8E	2*	16	"
May 13	39.2S	72.0E	....*	16	"
26	19.3S	76.3E	trace	16	"
30	10.4S	75.8E	1	16	Elster and Geitel

*Potential less than 500 volts.

tions. As was to be expected, a low potential gradient was in general associated with a high conductivity and vice versa. Thus when the conductivity was very low, during a fog, the potential gradient was high. The potentials observed were always positive. Table III gives the results.

TABLE III.

Potential Gradient Observations on the Second Cruise of the Carnegie.

Date	Latitude	Longitude	Mean Ship's Time	Potential Range	Mean Potential	Remarks
1911	°	°	h	+	+	
Feb. 23	36.2S	52.4W	10.0	70–120	90	
25	36.4S	50.4W	9.5	88–102	94	
27	38.4S	45.0W	11.2	.....	80	Strong N.E. wind—choppy—a little spray flying.
28	39.2S	41.0W	10.4	.....	95	After a drizzle—spray flying—rather stormy—rough.
Mar. 1	39.5S	37.9W	3.2	55– 95	..	Calm day—potential very variable, especially in calms.
2	39.7S	35.4W	2.0	.....	65	Strong S. wind—heavy sea—spray.
8	41.3S	14.8W	16.1	120–180	..	Foggy.
8	41.3S	14.8W	16.3	50– 65	..	Fog cleared away.
8	41.3S	14.8W	16.6	80– 90	..	Clear.
9	41.2S	12.0W	10.0	210–240	..	Foggy.
10	41.2S	7.5W	9.0	.....	75+	In a drizzle—insulation bad.
10	41.2S	7.5W	16.1	60–110	..	Clearing up—sun shining.
11	40.9S	6.0W	9.0–10.0	55–100	80	Overcast.
13	39.5S	0.6 E	11.5	100–250	175	Nearly calm—sunny.
15	39.0S	4.8 E	14.5–15.0	50– 90	70	Calm—clear—smooth.
15	39.0S	4.8 E	15.5–16.0	100–150	115	" " "
16	38.5S	7.2 E	9.2	70–140	110	" " "
16	38.5S	7.2 E	12.1	100–125	..	" " "
18	37.0S	11.7 E	11.2	100–150	120	
19	35.1S	15.5 E	8.5	.....	110	Little variation—fine spray flying.
May 3	39.8S	38.3 E	11.1	50– 90	70	Calm and clear.
4	40.2S	41.4 E	11.1	55– 75	65	Overcast.
10	40.3S	62.3 E	10.5	60– 95	75	
11	40.3S	67.1 E	11.0	65–125	90	
12	39.8S	70.8 E	16.5	40– 60	50	Misty and squally.
14	39.4S	73.5 E	10.5	80–130	95	Clearing up—smooth—light wind.
17	38.6S	77.0 E	10.5	.....	50	Clear—smooth.
19	35.6S	77.6 E	10.2	40– 60	50	Overcast.
22	28.5S	76.9 E	10.8	60–100	75	In S. E. Trade Wind.
25	21.1S	76.5 E	10.8	50–100	65	In S. E. Trade Wind—Fine.

Carnegie Institution of Washington,
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ON THE NORMAL MAGNETIC ELEMENTS AT THE MAURITIUS MAGNETIC OBSERVATORY.

By L. A. Bauer.

During a visit on the *Carnegie* in August, 1911, I had occasion to look into the remarkably disturbed character of the site of the Royal Alfred Observatory at Pamplemousses, Mauritius. Mr. Claxton, while director, had already called attention to the disturbances disclosed by a painstaking and extensive series of declination observations made over an interval of several months at 893 stations, within the area surrounding the old and new sites of the absolute declination observations.[1] The declination at these two sites which were located approximately in a true north-south direction and only 90 feet apart, varied from 9° 15′, at the old site, to 10° 35′, at the new one; from comparisons made twice a day for one year, the adopted difference between the two sites was found to be, 1° 30′. The declinations for standardizing the magnetograph had been made with a Kew magnetometer since 1875 in the old magnetic pavilion where at present the horizontal intensities and dips are still being observed. In 1903 "it was decided to utilize the 12-inch theodolite for more refined observations of declination," the magnet used being that of the Kew declinometer; hence arose the origin of the new pavilion in which declinations are observed daily, in the morning and in the afternoon, near the times of elongation. Declinations with the Kew magnetometer in the old pavilion were discontinued in 1906.

The shore observations of the *Carnegie* required simultaneous comparisons between the instruments for ocean work, the *Carnegie* standard land instruments (C. I. W. magnetometer and an Earth-inductor), and the Observatory instruments (Kew magnetometer and Dover dip circle). It was, accordingly, necessary to select two additional stations besides utilizing the old pavilion; the arrangements in the new pavilion were such that it was not possible to make the declination comparisons there, but instead, they had to be made at the old site again and with the Kew magnetometer. A general examination of the observatory ground quickly showed that it would not be readily possible, owing to the distribution of the exposed magnetic rocks, to select any two points having precisely the same magnetic elements; the two auxiliary stations, used

[1] Claxton, T. F. Preliminary report on a survey of magnetic declination near the Royal Alfred Observatory, Mauritius Proc. Roy. Soc. A., vol. 76, 1905, pp. 507–511.

chiefly for the ship instrument comparisons, were accordingly placed in line with the central pier of the old pavilion and the former azimuth mark (azimuth, 1.'3 W. of S.), which is about 150 yards distant from the pier, called Station *A*. Station *B* was 6.41 meters south and Station *C*, 48.78 m. south of *A;* Station *D*, used exclusively for dips is the west pier in the old pavilion, this pier being regularly used for the Observatory dip observations. As above stated, the new site for Observatory declinations which we shall call *N*, is 90 feet or 27.4 m. south magnetic of *A*, hence a few feet east of the true north and south line, passing through *A*, *B*, and *C*. The attempt was made to have the magnets of the various instruments used all at the same height above the ground, as nearly as possible, viz., 1.32^{m} about at *B* and *C*, and 1.50^{m} about at *A* and *D*. The table below gives the approximate magnetic elements and station differences at the above points; west declination is counted as negative, as also south inclination.

Date, 1911	Station	Decl'n (West)	Incl'n (South)	Hor. Int. (*C. G. S.*)	Observers
		° ′	° ′		
Aug. 8, 9, 12	*A*	—9 24.0	—53 28.9	.23329	R. A. Observatory.
	A	23.4	24.3	28	"*Carnegie.*"
Aug. 8-14	*A-B*	—0 42.9	.....	+.00175	"*Carnegie*" and Obs'y.
	A-C	+0 29.1	.....	—.00223	
	B-C	+1 12.0	— 1 20.0	—.00398	"*Carnegie.*"
	D-B	.....	— 1 02.6	.....	
	D-C	.....	— 0 17.4	.....	

In addition, we have from Mr. Claxton's declination observations, as above cited, $A - N = +1° 30'$. I have reversed the sign so as to apply the quantity *algebraically* instead of numerically. Hence, there results $N - B = -2° 03'$, and $N - C = -0° 51'$.

However, Claxton's detailed survey showed even greater differences for points near each other than those above. He detected three well-marked foci,[2] as per table on opposite page.

Claxton also gives the values of horizontal intensity observed at seven stations in this locality, the mean result being 0.2207; the minimum is .1969, the maximum .2439, and the mean of these two values .2204. The mean dip for nine stations is —53° 27′; the minimum is 50° 21′, the maximum 58° 34′, and the mean of

[2] *Cf.* Ref. 1, p. 509.

the two, 54° 28′. It will be noted that, except for the dip, the mean of highest and lowest observed values agrees closely with the mean for all stations.

Mr. A. Walter, the present director, in 1899 observed the magnetic declination at 24 stations in different parts of the volcanic island of Mauritius, the values ranging from 7° 20′ W to 11° 35′ W and the mean of all being 9° 25′ W. The horizontal intensities were obtained at 12 stations, the results varying from .2163 to .2455, and the mean of all being .2310; the dips at six stations

Focus	Phase	Rectang'r Co-ord. from old pillar (*A*)		Declination reduced to constant mag'raph reading (West)	Distance between maximum and minimum (feet)	Mean gradient, maximum to minimum 1° in
		South (feet)	East (feet)			
				° ′		
1	Maximum...	+16.3	+24.7	—10 45	11.4	1.9 feet
	Minimum....	+18.3	+13.5	— 4 56		
	Mean.....	.....	.....	— 7 50		
2	Maximum...	+51.4	—13.7	—13 45	8.5	1.1 feet
	Minimum...	+53.4	—22.0	— 6 20		
	Mean.....	.....	.....	—10 02		
3	Maximum...	—34.3	+95.6	—12 50	23.5	4.6 feet
	Minimum...	+38.0	+72.6	7 45		
	Mean.....	.....	.....	—10 18		
	Mean of all.....			— 9 23.5	for about Jan. 1, 1905.	
	Mean of lowest minimum (4°56′) and highest maximum (13°45′)			— 9 20.5		

ranged from 54° 24′ to 55° 29′, and the mean of all was 55° 04′ (South).

Comparing Claxton's results on the Observatory site with those made at various points on the island by Walter, the extremely interesting fact is revealed that, within the region of the old and new declination piers, but 90 feet distant from one another, it is possible not only to get all the values of the magnetic elements obtained over the Island, but even to transcend them.

The observations made aboard the *Carnegie* in the vicinity of Mauritius will serve to throw further light upon what the values

of the magnetic declination might be at the Royal Alfred Observatory did the local disturbances not exist. Summarizing the available data and referring them all to 1911.6 with the aid of the continuous observatory observations, the table below is derived:

No.	Date	Latitude South	Longitude E. of Gr	Magnetic Elements			Remarks
				Decl'n	Incl'n	Hor. Int.	
		° ′	° ′	° ′	° ′		
1	1905.0	20 05.6	57 33.2	—9 24	—53 27	.2207	Mean results of Claxton survey.
				— 11	+ 26	—.0034	Reduction,[3] to 1911.6.
	1911.6			—9 35	—53 01	.2173	Reduced to 1911.6
2	1899.5	20 17	57 34	—9 25	—55 04	.2310	Mean results of Walter survey.
				+ 9	+ 48	—.0059	Reduction,[3] to 1911.6.
	1911.6			—9 16	—54 16	.2251	Reduced to 1911.6
3	1911.6	20 05.6	57 33.2	—9 24.0	—53 28.9	.23329	R. A. Obs'y inst'ts.
4	1911.6	20 05.6	57.33.2	—9 23.4	53 24.3	.23328	C. I. W. instru'ts.
5	1911.6	20 35	57 54	—9.1	.....	.....	"Carnegie" sea observations.
6	1911.6	20 04	57 29	—9.5	54.0	.228	

Nos. 3 and 4 should be regarded as preliminary values.

No. 6 in above table is the mean of several observations made in the harbor about four to six miles almost due west of the Observatory; the declination values vary from about 9°.2 West to 9°.8 West, thus indicating the presence of local disturbances. This site has been used at times for getting compass deviations from ship swings, *e. g.*, by H. M. S. *Sealark*, in 1905.

It would appear from the above exhibit that the declination as observed on the old observatory pier (*A*) comes very close to what the undisturbed value would be. It is therefore fortunate that the results obtained at the new site (*N*) which, as found by Claxton, are on the average about 1° 30′ greater numerically, have all been referred to the old site before publication.

As far as the present data would enable one to judge, the Observatory published dips may be about one-half degree lower and the horizontal intensities about 0.005 C. G. S. higher than the undisturbed values would be; however, further data will be required.

On board the Carnegie,
Colombo, Sept. 8, 1911.

[3] In getting these, the values obtained with the Observatory instruments alone in 1911.6 were used, viz.: No. 3.

LETTERS TO EDITOR

AUSTRALASIAN ANTARCTIC EXPEDITION, 1911.

I am enclosing you a copy of certain magnetic term days which it is hoped you will be able to keep at your Observatory. This scheme of days has been drawn up by Dr. Chree, of Kew Observatory, Dr. Shaw, Director of the Meteorological Office, London, and myself. We carefully considered the advisability of continuing the observations for a whole year and concluded that whilst it was highly desirable in the case of the Australasian Expedition and the German Expedition and the Observatories at Mauritius, Melbourne, and Christchurch, it was not so necessary at observatories more remote from the South than these and the months of February, November, December, 1912, and January, 1913, are therefore omitted from the general list. There is, however, no doubt that the Expedition will have their Observatory in operation during these months and I am therefore to ask you, as the Director of one of the Southern Stations, to kindly aid by running your magnetographs at the highest speed during the enclosed additional hours. I may point out that some part of the interest attaching to these observations is due to the fact that there will be two Expeditions on opposite sides of the Magnetic Pole, viz., the German in the Weddell Sea, and the Australasian Expedition, west of Cape Adare and almost due west of the Magnetic Pole.

Whilst I am not acquainted with the equipment magnetically of the German party (which, however, I have no doubt is excellent) I can state that partly owing to magnetographs purchased by himself, but more particularly to the extreme generosity of the Carnegie Institution of Washington, through its Department of Terrestrial Magnetism, Dr. Mawson's Expedition is exceptionally well furnished with instruments and I have no doubt that in the hands of the capable observers, giving the Antarctic Observatory's test from the Weddell Sea and from northwest of the Magnetic Pole will be well done. We hope, therefore, that by the aid of your enthusiastic co-operation a considerable contribution may be made to our knowledge of the subject.

ADDITIONAL TERM HOURS FOR SOUTHERN OBSERVATORIES.

8 to 10 a. m. forenoon, G. M. T.

February 20th, 1912
November 5th, "
December 3d, "
December 31st, "
January 28th, 1913

5 to 7 p. m. afternoon, G. M. T.

February 22d, 1912
November 7th, "
December 5th, "
January 2d, 1913
January 30th, "

London, July 31, 1911. C. COLERIDGE FARR.

Memorandum by Dr. Shaw.

It has been arranged that a scientific expedition to be called the Australasian Antarctic Expedition, should proceed to the Antarctic continent from Australia about the close of this year with a complement of about fifty men, all told. The special desire of the expedition is to accomplish a complete geographic and magnetic survey along the coast of the Antarctic continent between Cape Adare and Gaussberg, a distance of over 2,000 miles. An oceanographic survey of the Southern Ocean, South of Australia, assisted by the Prince of Monaco, and meteorological observations will also be undertaken. There is to be no attempt to reach the South Pole. The expedition is supported chiefly by Australia and New Zealand, but help and advice have also been obtained in England and America.

The leader of the expedition is Dr. Douglas Mawson, who accompanied Sir Ernest Shackleton on his recent journey to the Antarctic, and was one of the leading members of Shackleton's party. Professor C. C. Farr, of Canterbury College, New Zealand, is arranging the programme of magnetic work.

Dr. Mawson is anxious to perfect his arrangements for obtaining accurate records of terrestrial magnetism in the Antarctic. He is to take a complete set of Eschenhagen magnetographs, and he wishes to arrange for "quick runs" of the recording apparatus to take place simultaneously at his base and at the principal magnetic observatories of the world. It is hoped to secure the co-operation of the German Antarctic Expedition, which has already started for the far South.

I have been asked to invite international co-operation in regard to the magnetic work at the times indicated here under by Dr. Chree of Kew Observatory.

I have the honor cordially to invite your assistance in this enterprise and should be glad if you could arrange for the quick runs to be made at the observatory under your charge.

As the primary purpose of a "quick run" is to facilitate the determination of the exact times of commencement of magnetic disturbances, it is specially requested that accurate time marks should be made on the records obtained during the term hours.

W. N. SHAW.

Meteorological Office, London, July 4, 1911.

Memorandum by Dr. Chree.

The magnetograph records obtained in 1902–03 by the stations of Prof. Birkeland's Norwegian Arctic Expedition, and by the British National Antarctic Expedition under Captain Scott, showed that many at least of the comparatively small disturbances, which are of common occurrence in temperate latitudes, are associated with much larger disturbances in high latitudes.

The large size of the Arctic and Antarctic movements facilitates the recognition of definite stages in the disturbance, and a comparative study of them and of the corresponding smaller movements occurring elsewhere is likely to suggest points of significance in the disturbances in temperate latitudes which would be unlikely otherwise to attract attention.

One of the chief difficulties in the intercomparison of ordinary magnetic curves arises from uncertainties as to the exact times at which particular movements occur. This difficulty can be largely reduced by increasing the rate of travel of the photographic paper.

These considerations point to the desirability of a series of quick runs of magnetographs during the stay in the Antarctic of the Australasian Expedition shortly to start under Dr. Mawson.

Your participation is accordingly requested in the following scheme of term hours which has been got out at the request of Dr. Mawson:

From 8 to 10 a. m. (forenoon) G. M. T.

1912		1912	
March	19	July	16
April	16	August	13
May	14	September	10
June	11	October	8

From 5 to 7 p. m. (afternoon) G. M. T.

1912		1912	
March	21	July	18
April	18	August	15
May	16	September	12
June	13	October	10

Your attention is particularly called to the fact that the hours are Greenwich civil time. The dates—all Tuesdays or Thursdays at Greenwich—are sufficiently near to new moon to facilitate the observation of aurora in the Antarctic. The hours have been selected from a consideration of the phenomena observed during the Antarctic Expedition of 1902–3. The hours 8 to 10 a. m., G. M. T., were those of most frequent occurrence of a special type of disturbance, which seems closely similar to, if not identical with, the Arctic disturbances called "Elementary polar storms," by Prof. Birkeland; while the hours 5 to 7 p. m., G. M. T., were those when rapid oscillatory movements were most in evidence at the "Discovery's" Winter Quarters.

NOTES.

16. Halley's autograph. It was neglected, inadvertently, to mention that the copy from which Halley's autograph signature was reproduced in Plate III of June number, was kindly supplied by *Sir Joseph Larmor*, Secretary of the Royal Society.

17. Dip Circles versus Earth Inductors. We are at times requested to express an opinion both as to the relative accuracy of these two totally different types of instruments for measuring the magnetic inclination, and as regards the relative advantages, one over the other. For a fixed observatory, or whenever the highest attainable accuracy is striven for, there can be but one decision, viz., to employ the earth inductor of modern type, such as made for example by the Potsdam mechanicians. Considerable experience has now been had with these instruments in all parts of the globe and we have not yet heard of anyone who, after having once become familiar with the earth inductor, would return, voluntarily to the dip circle. The earth inductor, when once set up, can be made to yield a result, in ten to fifteen minutes, possessing a relative accuracy certainly five times that of a determination from an hour's work with a good dip circle.

The absolute accuracy is likewise much superior to that of the average dip circle; comparisons have shown that while earth inductors differ among themselves by a few tenths of a minute, dip circles may differ several minutes. Such experience as is available would also seem to point to the fact that the small earth inductor corrections are less liable to change with alteration of magnetic field than dip circles. For survey work, the present form of earth inductor is not well adapted and it would be no gain in time to use it. It may be stated, however, that when the observers on board the *Carnegie* are given their choice whether to compare the ship dip circle ashore with a standard land dip circle or with the earth inductor carried on board, they invariably give preference to the latter. It is hoped ere long to make the earth inductor more suitable than at present for magnetic survey work.

18. A memorial to Gauss. The Electrical Review, of Chicago, states that a tower in honor of the great physicist, Gauss, has been erected on the Hohenhagen, a hill 508 meters in height, near Dransfeld, Germany. The tower is a square four-story structure, thirty-five meters in height, built of basalt, with a pyramidal roof. The interior has been fitted up as a Gauss museum.

19. Personalia. Dr. F. G. Figg, Chief Assistant for more than a decade, and later Director, at the Hongkong Observatory, has retired from active service. He is succeeded in the directorship by Mr. T. F. Claxton, previously Director of the Mauritius Observatory. *Admiral Herz* has retired from the directorship of the German Nautical Observatory at Hamburg. *Dr. William Sutherland*, of Melbourne, Australia, died suddenly on October 4th. The Council of the Royal Meteorological Society have awarded the Symons Gold Medal to *Professor Cleveland Abbe*, of the United States Weather Bureau, in recognition of the valuable work which he has done in connection with meteorological science; the medal will be presented at the Annual Meeting of the Society on January 17, 1912.

20. Errata. Page 85, in date of letter read December 20, 1910, instead of December 20, 1911. Table II, page 135, last entry under date of August 1st, for 13.1 in column of British chart values, read 13.3, and for —1.0 in column of British chart errors read —0.8; last entry under date of August 2nd, for 13.0 under U. S. chart values read 13.5.

21. Lectures on Solar and Terrestrial Physics. A course of lectures was given October 17, 19, 20, 23, 24, 25, 26, 1911, in the Physical Laboratory of the Johns Hopkins University at Baltimore, by Arthur Schuster, F. R. S., Honorary Professor of Physics in the University of Manchester. The object of the lectures was to discuss the cosmical applications of recent advances in physics, to explain the methods of examining correlations between solar and terrestrial phenomena, and to specify the problems of solar and terrestrial physics which seem to call for special investigation. The general scope of the lectures was as follows:

1. Preliminary Considerations. The ponderomotive forces concerned (gravitation, radiation pressure, electrostatic forces). The laws of radiation (adiabatic, isothermal and radiostatic equilibrium). *2. The Sun.* The interior of the sun, conditions at the surface due to ejection of electrons. Spectroscopic phenomena and their interpretation. The laws of solar rotation. The sun's corona. Sun-spots and their periodicity. *3. Interplanetary Space.* Effects of small quantities of matter on thermal and electric conductivity. *4. The Earth.* Our knowledge of its interior constitution. The age of the earth. The prin-

cipal phenomena of terrestrial magnetism and atmospheric electricity. *5. The Earth's Atmosphere*—more especially with regard to its condition near its upper limit. *6. General methods of investigating periodicities.* Brückner's "35-year meteorological cycle" shown to be non-existent. Lunar effects. Connection between sun-spots and terrestrial phenomena.

22. Ocean Magnetic Observations Aboard the Gauss, 1901-03.

A valuable publication[1] has been received containing the magnetic declinations observed aboard the *Gauss*, on the German Antarctic Expedition of 1901–03. While the observations were chiefly made by the physicist, *Dr. F. Bidlingmaier*, the navigation officers also secured observations as opportunity afforded. It is extremely unfortunate that the intelligent zeal and painstaking care displayed was vitiated by the unsuitable appliances with which Dr. Bidlingmaier was compelled to work. Instead of reaching a possible accuracy of 0°.1 in ocean magnetic declinations, as he himself set, he finds now that his own results can hardly be relied upon closer than about one-third degree, taking account of uncertainty of deviation corrections, the *Gauss* not being a strictly non-magnetic vessel; the officers' results, due to various causes, may be in error one-half degree. In the region of St. Paul and New Amsterdam Islands, where it was possible to form a mean separately of several stations, first for Bidlingmaier's results, secondly, for those of the officers, the two means, although referring to the same position, latitude 35¼° S., longitude 74¾° E., differed 0°.8 from each other, doubtless to be ascribed chiefly to uncertainty of deviation correction; for other means formed, the difference was not so large and at times vanished.

Although the errors in the present declination results are thus larger than desirable they nevertheless form an important contribution to ocean magnetic data. One must regret that they could not have been published earlier for advantageous use by other organizations; perhaps it will not be long now before the dip and intensity results will also appear.

A typographical error is noted on plate VI, where the value for May 2, 1903, is given as 20°.7 instead of 20°.1; also on page 340 the value for No. 66 is put down as 24°.9 instead of 24°.0.

Some secular variation data are derived by a comparison of the results of the *Gauss* with those scaled from Sabine's chart of 1840–45, and from Creak's chart of 1880; the average change per annum for the later period is shown on plate VII, along the track of the *Gauss*. Such results, of course, are subject to errors of the charts used, which may amount in some regions to several degrees, affecting the average annual change to the extent of possibly fifty per cent, and even causing a reversal of sign; this may be especially true in regions of the Indian Ocean, for example, not covered by the *Challenger*, on whose data the 1880 chart was largely based.

The author finds that the chart errors are frequently systematic in their nature and largely due to erroneous secular change corrections; he thus confirms the results already announced for the *Galilee* in the Pacific Ocean, 1905–08, and by the *Carnegie*, 1909–10, in the Atlantic Ocean.

[1] Deutsche Süd-polar Expedition, 1901-'03. Erdmagnetische See-Beobachtungen, etc., von Dr. F. BIDLINGMAIER, II Theil, Declination. Berlin, 1911. Pp. 315-342, 3 plates.

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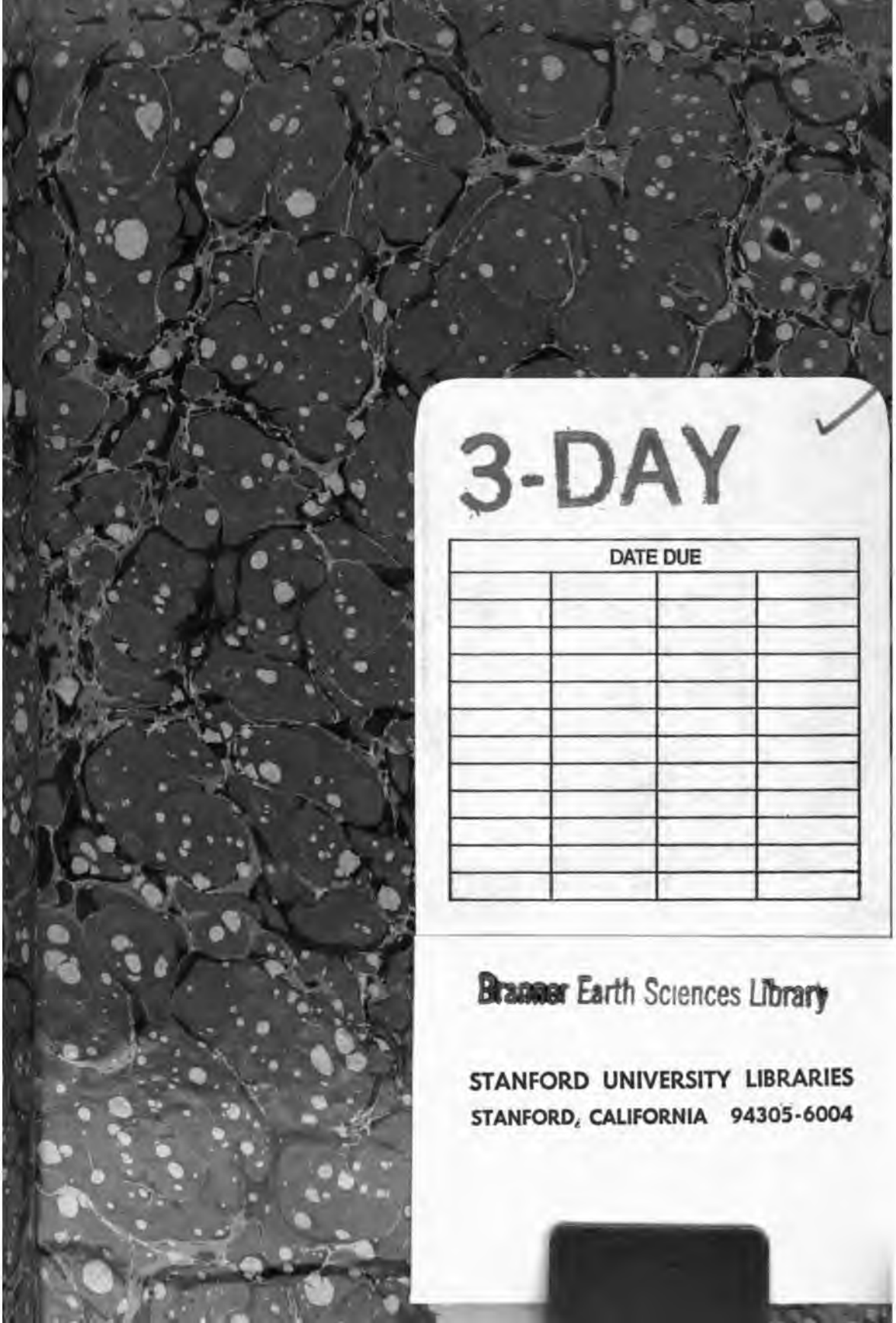

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